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AN EVALUATION OF STRATEGIES FOR AIRPORT AIR POLLUTION CONTROL

ARGONNE NATIONAL LABORATORY

PREPARED FOR
ENVIRONMENTAL PROTECTION AGENCY

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AN EVALUATION OF STRATEGIES FOR AIRPORT AIR POLLUTION CONTROL

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16. ABSTRACT

This report is the second phase of a program to develop an airport air pollution impact methodology. This work was coordinated with a field test program at the Hartsfield Atlanta International Airport involving modifications to aircraft ground operations to achieve emission reductions. In addition to evaluating the effect of controls on airport and regional air quality, the airport planning process was investigated to determine the points at which alternate strategies might be implemented. The principal evaluative tool was the Argonne Airport Vicinity Air Pollution Model which is a Guassian plume description of pollutant dispersion. The five control strategies for aircraft studied were: 1) engine shutdown during taxi, 2) towing aircraft between runways and terminal gates, 3) capacity control, 4) fleet mix control, and 5) engine emission standards. The study showed engine emission standards to be the most effective overall. Towing and fleet mix control provide substantial CO and HC air quality improvements, but fleet mix results in a substantial increase of NOx emissions. Engine shutdown and capacity control provide only small air quality improvements. The study is designed to provide an insight into the effectiveness of various control techniques at the Atlanta Airport as well as develop a usable methodology which might be applied to studies at other airports.

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by

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The Environmental Quality Division, the Aircraft Safety Division, and the Atlanta Airport Operations Office of the FAA lent considerable help in data acquisition. The Mobile Source Pollution Control Program, the National Environmental Research Center/Las Vegas, and the Region IV Office of the EPA also assisted in the collection of data. The Georgia Department of Natural Resources provided substantial help in the assembling of a regional emission inventory.

A note of thanks is due to all the airlines serving Atlanta for their completion of the data questionnaire. The staff of Delta Airlines, and especially Mr. Don Brown of Facilities, were exceedingly helpful in the collection of necessary information.

Finally, it is with sadness that we note the death of Mr. Donald P. Armstrong, formerly of the Land Use Planning Branch of EPA, under whose direction both phases of this program were initiated. Our appreciation is extended to Messrs. David Tamny and Thomas McCurdy who served as project officers to the completion of the study.

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1.0 INTRODUCTION

The control of air pollution in the vicinity of airports is a complex problem because of the extent and diversity of the emission sources. This report presents the results of a study conducted by the Energy and Environmental Systems Division of Argonne National Laboratory and sponsored by the U.S. Environmental Protection Agency (EPA) and is the second phase of a program to develop an airport air pollution impact methodology. The results of Phase I are reported elsewhere.[1]

In a previous work[2] EPA evaluated several aircraft engine design changes and several ground operation modifications for their impact on reducing aircraft emissions. This work led to Proposed Standards for Control of Air Pollution from Aircraft and Aircraft Engines[3] in which aircraft engine emission standards were proposed and an Advance Notice of Proposed Rulemaking[4] in which modified ground operations were suggested. The emission standards in modified form[5] were eventually promulgated; the ground operational test procedures were subjected to a field test but have not, to date, been promulgated. The results of the field test at the Hartsfield Atlanta International Airport are published in other reports.[6,7,8]

The purpose of this study was to use the Atlanta field test as a starting point for an evaluation of the viability of alternative control strategies in reducing the air quality impact of aircraft operations. In addition to evaluating the effect of controls on airport and regional air quality, the airport planning process was investigated to determine the points at which alternate strategies might be implemented. The outputs of this study are designed to provide both an insight into the effectiveness of various control techniques at the Atlanta airport as well as to develop a usable methodology that might be applied to studies of other airports.

The principal evaluative tool used was the Argonne Airport Vicinity Air Pollution (AVAP) model, which is a Gaussian-plume dispersion model that has been developed in several versions with the support of the Federal Aviation Administration (FAA),[9,10] the U.S. Air Force[11,12] and the EPA. By using Hartsfield Atlanta as the study airport, it was possible to validate the model with the field test air quality and aircraft activity data. The five control strategies for aircraft studied were: (1) engine shutdown during taxi, (2) towing aircraft between runways and terminal gates, (3) capacity control, (4) fleet mix control, and (5) engine emission standards. The first two were proposed and evaluated to some extent in previous work.[2] The last one represents the aforementioned emission standards that have recently been promulgated.[5] The field test at Atlanta involved only the engine shutdown strategy.

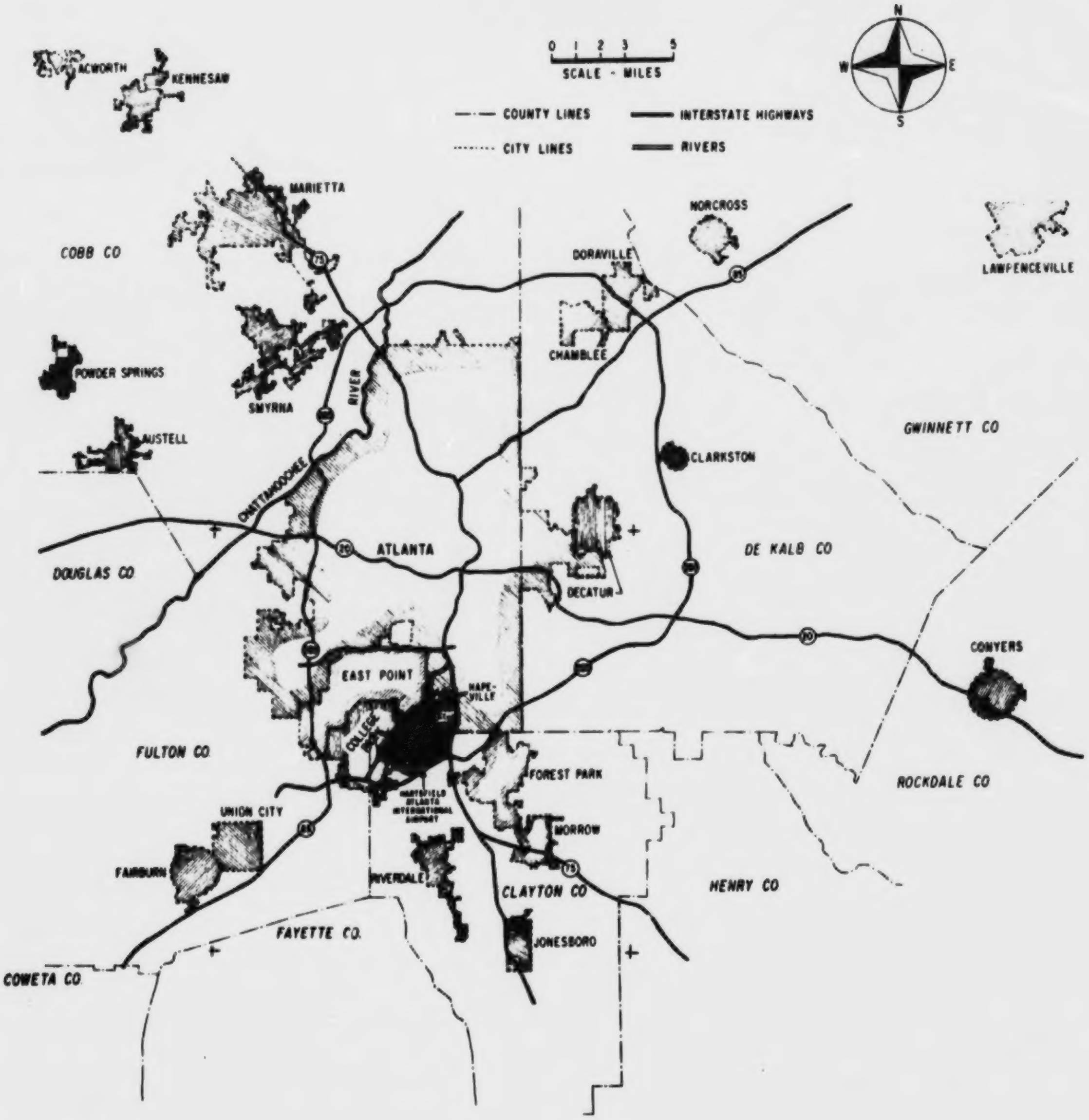
This study did not evaluate all possible aircraft control strategies, nor did it consider controls on other airport emission sources (e.g., ground service vehicles).

2.0 TEST CASE: HARTSFIELD ATLANTA INTERNATIONAL AIRPORT

2.1 FIELD TEST BACKGROUND

The EPA, in its Advance Notice of Proposed Rulemaking,[4] suggested that a possible means of reducing emissions at airports would be to have aircraft use fewer engines while taxiing to and from runways and the terminal area. The remaining engines would be operated at higher thrust settings to maintain taxi speed. Emission reductions would result from a lower total aircraft emission rate with fewer engines operating and from improved performance from the other engines as they were moved higher in power setting. In January, 1973, public hearings were held on the proposal. At the hearings, the FAA, the Air Transport Association (ATA), and the Air Line Pilots Association (ALPA) expressed reservations about the strategy based on safety considerations and practical limitations of aircraft, airports, and air traffic situations. An operational trial to test the feasibility of the modified taxi procedure was suggested.

The choice of a test case airport for the operational trial was a difficult one owing to conflicting requirements for a scientifically controlled test and a minimal interference with normal airport operations. The criteria by which the test airport was chosen included the following: the airport should have enough air carrier activity to experience delays in aircraft departure due to heavy runway use, the airport should not be in an area where background pollutant concentrations (that is, pollutants generated by non-airport sources) were high enough to mask any contribution from the airport itself, and the airport must be amenable to such a test procedure without affecting safety or operational efficiency. The William B. Hartsfield Atlanta International Airport was chosen since it best satisfied all the above criteria. The Atlanta Airport is the third busiest in the country in air carrier aircraft activity. Delay situations occur with enough frequency that a modification of taxi procedures could be expected to result in significant emission reductions. The airport, shown in Fig. 1, is located south of the City of Atlanta and is not in an area, such as Los Angeles, where unusual meteorology would distort the airport's impact on air quality. Finally, the strategy could be tested with a minimum of interference to normal airport operation.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ATLANTA
DE KALB CO
DOUGLAS CO
DECATUR
CONYERS
EAST POINT
HAPEVILLE
COLLEGE PARK
FULTON CO
FOREST PARK
ROCKDALE CO
HARTSFIELD ATLANTA INTERNATIONAL AIRPORT
UNION CITY
MORROW
FAIRBURN
RIVERDALE
CLAYTON CO
HENRY CO
FAYETTE CO
JONESBORO
COWETA CO

Fig. 1. Regional Location of the Atlanta Airport

Numerous groups were involved in the conducting of the operational test. The FAA participated through its Environmental Quality Division and Aircraft Safety Division and the EPA through its Mobile Source Pollution Control Program, Division of Meteorology and the National Environmental Research Center in Las Vegas. Three contractors, Mitre Corp., GEOMET, Inc., and Argonne National Laboratory, were also called in. Assisting in the test program were the Atlanta Airport Manager's Office, the Air Line Pilots Association, the Regional Offices of the FAA and the EPA, and each of the airlines serving Atlanta.

Mitre was charged with the responsibility of developing the actual operational test procedures that would be used by pilots flying into the Atlanta Airport. In addition, Mitre was to monitor the aircraft activity for total taxi time and reduced engine operating time. GEOMET was responsible for monitoring the air quality during the operational test in an effort to detect any changes resulting from the imposition of the control strategy. Argonne's responsibility was to use the Airport Vicinity Air Pollution Model to analyze the results of the test and to provide an analytical evaluation of the control strategy. GEOMET has published a separate report[6] on its findings using monitored air quality data as the primary analysis of the strategy, and Mitre is in the process of preparing a report[7] outlining its findings on the operational difficulties encountered and on the observed reduced engine operating time. An in-depth analysis of the strategy conducted by Argonne under the sponsorship of the FAA is published elsewhere.[3] The highlights of that study are included here.

2.2 AIRPORT DESCRIPTION

The William B. Hartsfield Atlanta International Airport in Atlanta, Georgia, is a major air carrier hub in the southeastern United States. It ranks third in the nation in air carrier aircraft activity and second in total aircraft activity. In addition to serving the aviation needs of the rapidly growing Atlanta metropolitan area, it serves as a major connecting point in the southeast. The airport is located in Fulton and Clayton Counties and is due south of the City of Atlanta (see Fig. 1).

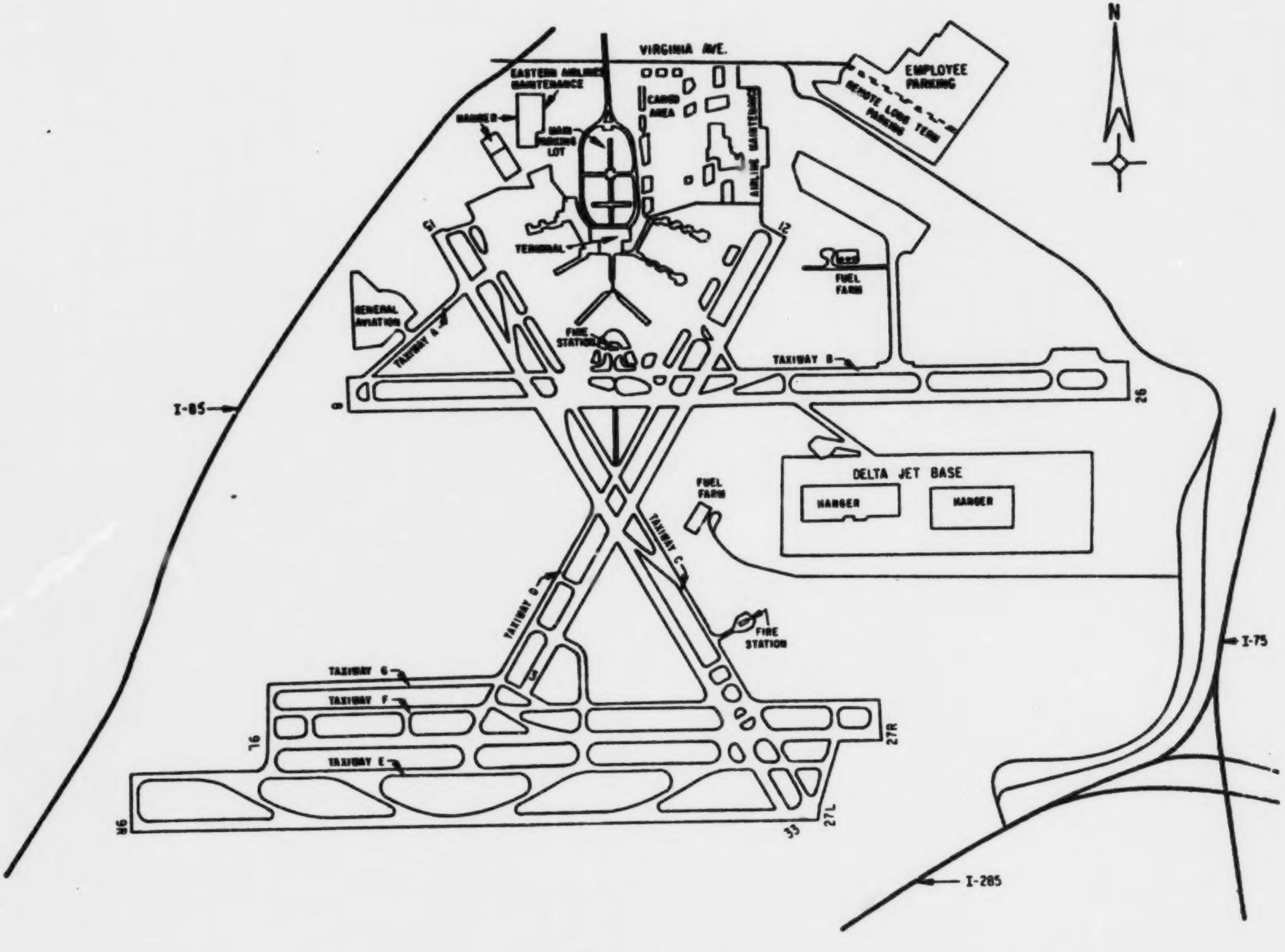
The airport configuration is shown on Fig. 2. There are three parallel east-west runways that carry virtually all of the traffic. Each is capable of handling jumbo jets and the separation distances permit simultaneous arrival and departure operations on the southern runways, 9L/27R and 9R/27L, along with operations on the northern runway 8/26. (Note that runway 8/26 has a designation code that is inconsistent with its actual direction. This is done to avoid the confusion of having all three runways with similar codes, e.g., 9L/27R, 9C/27C, 9R/27L.) Aircraft destined to, or arriving from, cities north of Atlanta will, in general, use runway 8/26, while those destined to or from cities south of Atlanta will use 9L/27R and 9R/27L. In periods of low activity, runway 8/26 is used almost exclusively because of its proximity to the terminal.

Two crosswind runways, 15/33 and 3/21, are also available. These are used for air carrier traffic only in highly unusual meteorological conditions and for small general aviation traffic unable to cope with crosswinds. For all intents and purposes, they can be considered as only taxiways between the southern runways and the terminal.

The Atlanta airport is served by 10 airlines: Delta, Eastern, United, Southern, Piedmont, Northwest Orient, TWA, National, Braniff, and Air South. Atlanta being its home base, Delta Airlines makes up the largest portion of the air traffic activity. Delta also maintains a major maintenance facility in a hangar complex located in the center of the field. Eastern has the next highest portion of air traffic and has a smaller, though still substantial, maintenance facility west of the terminal. Delta and Eastern together account for 75% of the air traffic.

In addition to the passenger carriers, several all-cargo airlines operate from the Atlanta airport. A cargo facility is located to the east of the terminal for these services. Adjacent to the cargo area is yet another maintenance area that serves limited needs of all the other airlines. A general aviation hangar and service area is located at the west end of runway 8/26.

The terminal building is north of 8/26 and has 64 gate spaces. In addition, Delta and Eastern make use of remote parking areas during peak hours and use buses and/or Plane-Mate vehicles to transport passengers between the terminal and the aircraft. Atop the terminal is a multistory office building that houses the air traffic control tower, FAA and airport management offices, and several commercial establishments.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TAXIWAY E
9L
9R
27R
27L
33
I-75
I-285

Fig. 2. Site Map of the Atlanta Airport

Ground access to the airport is via a connection to Interstate 85 and ramps from a main arterial, Virginia Avenue. A parking lot, immediately adjacent to the terminal is available, and a remote lot is used for long-term and employee parking. There is bus and limousine service to downtown Atlanta and to nearby motels and hotels.

2.3 FIELD TEST PROGRAM

2.3.1 Schedule

The field test covered a six-week period from November 9, 1973 to December 30, 1973. During the first two weeks, termed the Baseline Phase, airport operations were carried out using standard operating procedures. Observations of aircraft activity and airport air quality were made to establish the baseline parameters. During the second two weeks, termed the Amber Test Phase, the airport operated with modified ground operation procedures. Participating aircraft shut down one engine upon notice from the control tower and taxied with the remaining engines at a slightly higher power setting to maintain taxi speed. Aircraft activity and air quality observations continued in an attempt to detect any differences. The final two-week segment, termed the Amber Test/Gate Hold Phase, was added to the original test schedule as a result of circumstances surrounding the shortage of jet fuels in late 1973. The FAA had mandated a gate hold procedure at all major airports in an attempt to conserve fuel. Departing aircraft were held at the gate with engines off until estimated departure delays fell below 10-15 minutes. It was decided to maintain Amber Test procedures during this period to determine whether the dual strategy would have a measurable impact on air quality.

2.3.2 Operational Procedures

Table 1 indicates the extent of participation of the aircraft using the Atlanta airport in the Amber Test Phase. Aircraft exempted from the arrival and/or departure procedures were expected to experience some operational problems such as difficult maneuverability and inadequate functioning of aircraft systems if participation were required. In addition, the test conditions were suspended when there was rain, ice, or standing water on the taxiways, when instrument flight conditions were required on runway 8/26, and when the pilot determined the situation to be unsafe for the test.

TABLE 1. Aircraft Participation in Amber Test Control Phase

Aircraft Type	Participation
B-727, DC-10	Arrivals and Departures
DC-9	Departures only
B-707, CV-880, DC-8	Arrivals only
B-737, B-747, L-1011, M-404, YS-11, FH-227	Exempted

Participating arrival aircraft were advised from the control tower when Amber Test was in effect. Upon clearing the arrival runway and entering the taxiway, one engine was shut down and the aircraft proceeded to the terminal gate in this mode. Participating departing aircraft were advised when departure delays were expected to exceed 6 minutes. All engines would be started at the gate in normal fashion. Upon reaching a pre-selected checkpoint, the pilot would shut down one engine and proceed toward the duty runway. For aircraft using the southern runways, the engines were shut down just after clearing runway 8/26. For aircraft using runway 8/26, engines were shut down after clearing the ramp area. A second checkpoint, estimated to be approximately 6 minutes from takeoff and signaling engine restart, was marked with a small green sign placed next to the taxiway. Figure 3 gives the location of the engine restart points.

2.3.3 Data Acquisition

Data was collected by three contractors participating in the field test program: Mitre Corp., GEOMET, Inc., and Argonne National Laboratory. Mitre's prime responsibility was to collect aircraft activity data. Runway use patterns, total taxi time, and engine shutdown time were the variables of interest. Recordings of voice communications between Air Traffic Control and individual aircraft and visual observations were the main data sources. Airline records and FAA voice tapes were used for supplementary information. Observations were made for a three-hour period from 9:00 AM to 12:00 noon. It was often suggested that the observation period be moved to determine operational characteristics during other time periods, but the decision was never made to authorize Mitre to make the change.

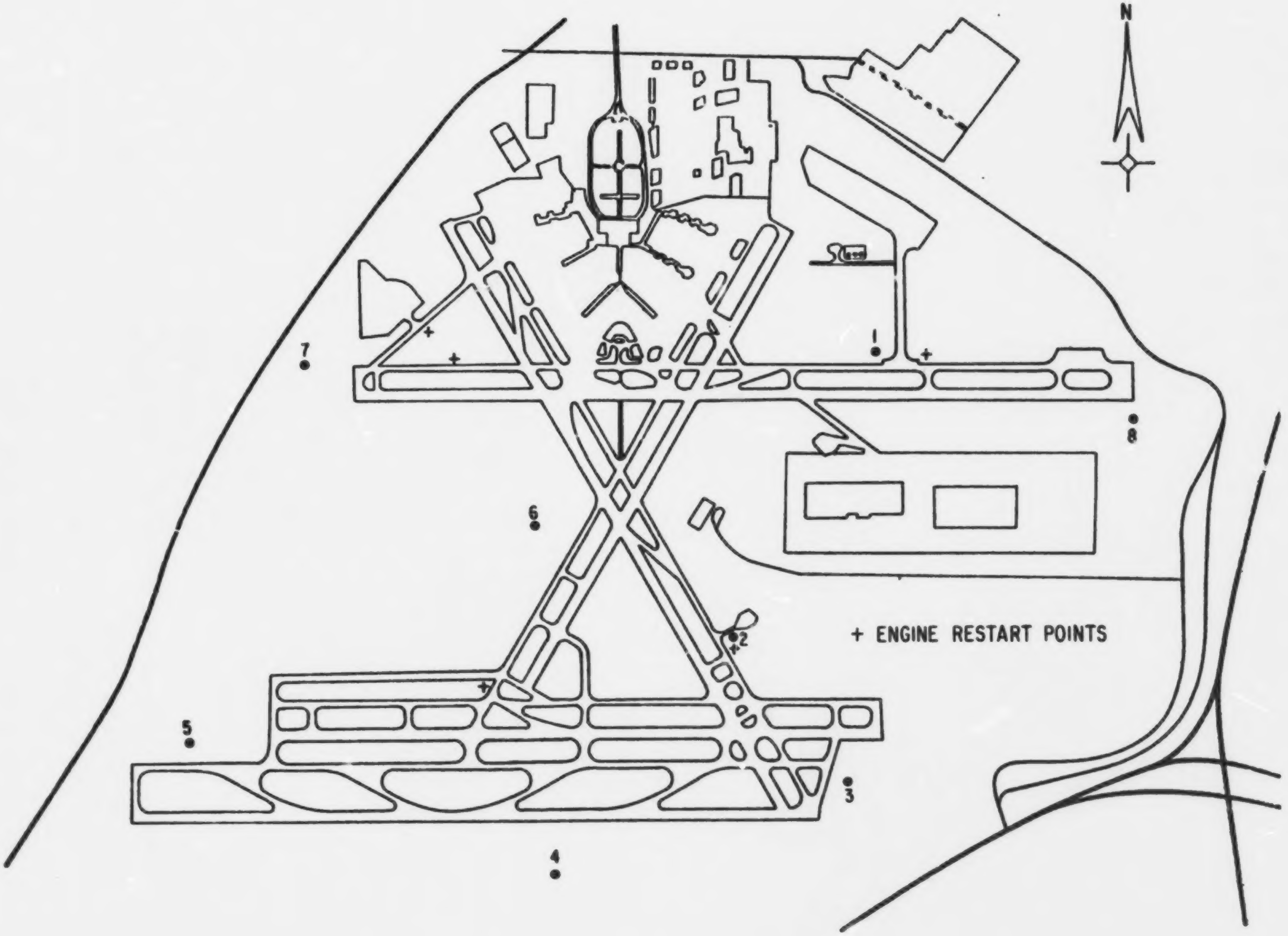
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Fig. 3. Map of Atlanta Airport Showing the Locations of the GEOMET Receptor Sites and Engine Restart Points for Outbound Aircraft

Mitre's data collection proceeded without any major difficulties and the resulting information presented no unusual behavior when analyzed. The major concern as to the validity of the reduced engine operating times was that there was no way of determining if, in fact, a pilot shut down an engine when advised from the tower that Amber Test was in effect. The tower communication for participating arriving and departing aircraft was simply "Amber Test in Effect" added on to the taxi clearance being given. No acknowledgement of engine shutdown was required from the pilots in order to minimize the impact on their busy routine during takeoff and landing operations. This deficiency was recognized at the start by Mitre, but there was no way of correcting it within the constraints of the program.

GEOMET's prime responsibility was to collect air quality data to determine if any change could be detected as a result of the imposition of the strategy. Eight monitoring stations were set up at various locations on the airport (see Fig. 3). Carbon monoxide was measured at all eight stations, total and non-methane hydrocarbons were measured at stations 2, 3, and 7, and windspeed and direction were measured at stations 2 and 7. Meteorological data from the National Weather Service station located atop the general aviation hangar were also collected.

GEOMET experienced considerable difficulty in getting the air quality monitoring stations to function properly. Some of the equipment, on loan from the National Environmental Research Center in Las Vegas, did not operate reliably and was, in addition, designed to read values much higher than were actually observed. A great deal of the hydrocarbon measurements were invalidated by a contaminated calibration gas received from a supplier. Finally, the duration of the field test program was recognized as being much too short to make statistically valid air quality observations. The constraints of the program again prohibited any correction of this deficiency. GEOMET's final report[6] gives a more detailed description of the air quality monitoring analysis.

Argonne's prime responsibility was to employ the Argonne Airport Vicinity Air Pollution Model to perform a dispersion analysis of the effectiveness of the Amber Test strategy. Data collection was aimed at building the data base necessary to run the model. A questionnaire was prepared and submitted to the seven major airlines at Atlanta. Information on passenger and cargo activity, load factors, employees, aircraft ground service vehicle requirements, fuel storage and handling facilities, engine test and maintenance facilities, and space heating and incineration equipment was collected. This data was transformed into estimates of air pollutant emission rates of these various activities. Observations of aircraft taxi speeds and terminal area aircraft activity were also made by Argonne staff during two weeks of the test period, one during the baseline phase and one during the Amber Test phase.

Information on air pollutant emissions from sources outside the airport that would contribute to the background levels at the airport was obtained from the point source emission inventory compiled by the Division of Air Pollution Control of the Georgia Department of Natural Resources and from traffic data from the Georgia Highway Department. Data from the Atlanta Regional Commission and the Bureau of the Census were also assembled for the Atlanta area.

2.3.4 Impact of the National Fuel Shortage

Late in 1973, jet fuel came into short supply as a result of the embargo placed on oil shipments to the U.S. by the Arab nations. Unfortunately, this occurred in the middle of the field test program. Since aircraft activity was not observed for all hours of the day, it was impossible to determine the direct impact of the fuel shortage on air traffic. Estimates indicated that air carrier flights in December declined by approximately 10% of the November traffic levels. Since this was the peak period for vacation travel, the majority of the cuts were in the off-peak hours of early morning. The impact on the key hours of high aircraft activity was therefore thought to be minimal.

In addition to the effect on air traffic, the fuel shortage resulted in some changes in the normal operating routine of the airport. Aircraft fueling schedules were shifted, with some airlines using Atlanta as a tanker point thereby refueling more than normal and other airlines not taking on the usual complement of fuel at Atlanta. It was also observed that some airlines were using the pushback tractors to tow aircraft to the edge of the ramp area in an effort to minimize unnecessary idle time. The use of a gate-hold procedure for departing aircraft has already been mentioned. Finally, as the airport is surrounded by heavily traveled interstate highways, reduction of motor vehicle traffic, especially on Sundays when gas stations were closed, undoubtedly influenced the background pollutant concentrations observed.

It was not possible to make even a first order approximation of the effects of these conditions on the test program. It can only be presumed that by focusing on the high traffic periods during weekdays, the impacts of these perturbations could be assumed to have been minimal.

2.4 TEST RESULTS

The test results can be described as inconclusive at best. Despite the problems that prohibited a more definitive conclusion, several important considerations surfaced and the experience was a valuable one. Details of the conclusions arrived at by Mitre and GEOMET can be found in their respective reports.

From the standpoint of airport operational procedures, the Amber Test made no serious impacts on pilot or control tower efficiency and workload. The imposition of an Amber-Test-like procedure on arriving aircraft appears to have the potential of becoming a standard operating practice that could be implemented on a regular basis. The engine shutdown created no serious problems in aircraft handling and had a fuel conservation effect in addition to emission reduction. For departing aircraft, Amber Test is of questionable value, at least at the Atlanta airport. It was imposed only 13 times during the two-week test period. The longest time was for 4 hours and 40 minutes on December 4, but the next longest time was only 29 minutes. Table 2 gives the summary as compiled by Mitre.

In addition to infrequent use of the departure test conditions, the engine shutdown and restart points were not located to optimize total engine shutdown time. It became evident that the restart points were, in general, too far from the end of the runway. The time from engine restart to takeoff varied from 4-12 minutes instead of the desired 6 minutes. A more flexible restart point as determined by the pilot might have had greater impact.

Furthermore, departing aircraft under Amber Test conditions continued to start all engines in the terminal area. This negated any effect that the strategy might have had where the pollutant concentrations from aircraft were the worst. It does not seem possible to require all aircraft to start one less engine at the gate because of maneuverability problems encountered with a fully loaded outbound aircraft.

TABLE 2. Application of Departure Amber Test Procedures[a]

Date	Length of Application (Hr:Min)	Runways
12/1	:11	26
	:20	27R
12/2	:06	9L
12/3	:15	8
12/4	4:40	8, 9L, 9R
12/6	:16	26, 27R
	:10, :07	27R
	:29	26
12/7	:07	27R
12/10	:20	26
12/12	:15, :13	26
12/13	Unknown	27R

[a] Mitre Corp. data.

The gate hold strategy fell victim to the same shortcomings as Amber Test for departing aircraft. It was infrequently used and only for short periods. Gate hold procedures place an additional burden on the air traffic controllers and are not likely to find widespread acclaim.

Despite the above-mentioned shortcomings, the imposition of Amber Test conditions does, in fact, result in reduced engine operating time. Arrivals averaged about 3 hours of engine shutdown time per hour of airport operation during the 9:00 AM - 12:00 noon period. This must, of necessity, result in a measurable reduction in emissions and corresponding fuel savings.

GEOMET's analysis of the air quality data showed no statistically significant change in CO concentrations as a result of either the Amber Test or Amber Test/Gate Hold strategies. The aforementioned problems with test schedule and equipment does not make this result unexpected. Initial evaluations of the potential impact on air quality indicated that only a small change could be anticipated, and in order to detect this change experimentally, a large amount of data is needed to smooth out perturbations in meteorology and aircraft activity. Previous monitoring programs at airports have shown the magnitude of the difficulties presented by these perturbations. The wide variation in CO concentrations observed at Atlanta for meteorological and aircraft activity conditions that were identical reinforces this conclusion. It is, therefore, not surprising that this change could not be observed.

Analysis of the results obtained from the Argonne Airport Vicinity Air Pollution Model is presented in the following sections.

3.0 MODEL DESCRIPTION AND VALIDATION

3.1 MODEL STRUCTURE

The Argonne Airport Vicinity Air Pollution (AVAP) model was used as the major evaluative tool in this study. There are several versions of the computer package, the details of which have been published elsewhere.[9,10,11,12] Only a brief capsule summary of the model will be presented here.

The computation of air pollutant concentrations using the AVAP model is a two-stage process. First, the pollutant-producing activities at the airport and in its vicinity are quantified and transformed into emission rates by the application of emission factors. The output of this stage is a spatial and temporal description of the emission pattern as a series of point, area, and line sources. The second stage of the model computes air pollutant concentrations using the source inventory. There are two options available; one calculates concentrations for short-term and the other for long-term averaging times.

3.1.1 Source Inventory Program

The source inventory program includes six basic airport emission source categories: aircraft, ground service vehicles, access traffic, engine testing facilities, fuel storage and handling, and space heating. Also included are point, area, and line source descriptions for non-airport environ sources.

A complete geometric and kinematic description of an aircraft's flight path in the vicinity of the airport and ground route between terminal and runway is used in the model. The activities which are simulated include engine startup, idle, taxi-out, engine check, takeoff, approach, landing (including thrust-reverser use), taxi-in, and engine shutdown. Each activity has associated with it a time-in-mode and an air pollutant emission rate that are used to determine the total emissions. Several algorithms can be selected to represent different aircraft types and varying operational procedures.

Most of the aircraft emissions are treated as finite line sources. The approach and climbout flight paths extend to an altitude of about 3000 feet, and the simulated ground taxi paths are those most frequently used. In the terminal ramp area the aircraft emissions are treated as area sources as are emissions at aircraft pause points.

Emissions from the ground service vehicles are included in the terminal area sources. The type and service time of each piece of equipment (e.g., tractors, baggage trucks, food service trucks, fuel trucks, etc.) are used to estimate a total ground service vehicle emission rate associated with each aircraft type. The emissions can then be linked directly to the aircraft activity pattern.

Emissions from access traffic is modeled as both area and finite line sources. The main roadway links to the airport are treated as lines and the parking lots as areas. In addition to estimating emissions from moving vehicles, the model can account for emissions from vehicle cold starts and evaporative losses.

The operation of aircraft engine test facilities, both runup stands and test cells, are included in the source inventory. The testing schedule is used to derive an emission rate using the aircraft emission factors.

Evaporative and breathing hydrocarbon losses from the storage and handling of the large quantities of jet fuel, aviation gas, and automotive fuel is accounted for in the model using both point and area source descriptions. The variation in tank size, construction, and operation can be simulated and a special routine handles fuel tank trucks.

Emissions from the heating of the terminal, hangars, maintenance and other buildings were modeled as point sources.

For the above well-defined emission sources on the airport the model is designed to accept activity parameters; emission factor data included in the program relieves the user of the burden of transforming the activity into emissions. The model will also accept miscellaneous point, area, and line emission source descriptions to handle sources that do not fall into the above categories.

In the interest of general applicability of the model, the environ emission sources are not as firmly categorized as the airport sources. Rather, the model is designed to accept, as input, emission data (rather than activity data) for all environ point, area, and line sources. The only exception to this is that area sources may be subdivided into mobile and stationary emission categories. For mobile area sources, the user may input vehicle activity and make use of the emission factor routines in the model to compute emissions.

All other non-mobile area source emissions are included in the stationary area source information.

A complete discussion of the procedures used to develop a data base for airport air pollution analyses was presented in the final report of Phase I of this project.[1] Summaries of key portions of the data sets will be presented in the body of the analysis.

3.1.2 Dispersion Model

Both the long- and short-term versions of the dispersion model are designed to allow maximum use of "state-of-the-art" techniques for computing dispersion from a multisource inventory of point, area, and line sources. The Long-Term Model (LTM) is used to compute monthly or annual average air pollutant concentrations using historical meteorological records. The Short-Term Model (STM) on the other hand is used to compute hourly average air pollutant concentrations using the corresponding hourly average values of the meteorological data. The latter model can be applied to a sequence, of arbitrary length, of hours corresponding to either real or hypothetical source activity and meteorological conditions. The computer programs corresponding to these models were structured in a way such that many of the computer subroutines are common to both programs.

The principal differences between the STM and the LTM arise from the fact that the STM uses a prescribed condition approach while the LTM uses a statistical approach. That is, the STM computes the concentration at a receptor corresponding to a particular hour for which the source characteristics and meteorological conditions have been defined. On the other hand, the LTM computes the monthly or annual mean concentration without reference to the concentration for each individual hour in the month or year. The major assumption of the statistical approach used by the LTM is that the long-term average concentration at a given receptor can be represented as a sum of long-term average contributions coming from each source. The long-term average contribution from each source can, in turn, be represented as a sum over the contributions occurring under all possible distinct meteorological conditions weighted by the frequency of occurrence of each of these conditions. For convenience, the continuum of possible meteorological conditions is reduced to a set of 576 combinations by defining 16-22.5° wind direction sectors, 6 wind speed ranges, and 6 atmospheric stability classes. Each of these 576 combinations is referred to as a "met set." Corresponding to each met set and source-receptor pair is a quantity called a "coupling coefficient," which is the source contribution to the concentration at the receptor for the met set and unit source emission rate. To obtain the contribution of a source to a receptor for a specific met set and pollutant source emission rate, one simply multiplies the appropriate coupling coefficient (of which there are 576 for each source-receptor pair) by the pollutant emission rate.

Since each met set is defined in terms of a 22.5° wide wind sector, in contrast to the hourly average wind direction as used by the Short-Term Model, it is not possible to use precisely the same dispersion equations in both models. However, an effort has been made to make the two models as nearly alike as possible. For example, the treatment of plume rise and the Briggs' downwash effects are precisely the same in both models and the use of a wind profile law is quite similar in both models. The basic line source model is precisely the same in both models, but in order to incorporate the wind direction dependent line source model into the Long-Term Model framework, it was necessary to develop an angle averaging procedure, which, for computational efficiency, utilizes Gaussian quadrature techniques. The main detailed difference between the two models lies in the equations used in the treatment of dispersion from physical point and area sources. Both models assume Gaussian distributions in the vertical direction, but only the Short-Term Model considers Gaussian-type dispersion in the lateral direction as well. Furthermore, whereas both models treat the finite size of physical sources by the artifice of pseudo upwind point sources, the technique is used only for the horizontal dimension of the source in the Long-Term Model. The technique for computing the location of the pseudo upwind point source also differs in the two models.

It should be noted that although the general framework of the Long-Term Model resembles the original Air Quality Display Model (AQDM), many detailed modifications have been made including use of the six Turner stability categories[31] to compute the vertical dispersion coefficient, changes in the computation of plume rise and incorporation of downwash rules, addition of a wind profile law, addition of the line source model, modification of the mixing depth algorithm, generalization of the climatological-dispersion approach to allow for monthly, as well as time-of-day dependent, computations of air quality, expansion to allow for more pollutant species, and various other changes. For a complete discussion of the model algorithms, the reader is referred to the previously cited reports.

3.2 VALIDATION RESULTS

Air quality monitoring carried out by GEOMET during the field-test period provides data that can be compared with air quality levels calculated with the airport vicinity model. Substantial amounts of monitored data are available only for carbon monoxide. Problems with monitoring apparatus and with purity of reference gas sources caused the attempted monitoring of hydrocarbon levels to be only partially successful. Consequently, comparison between observed and calculated air quality levels has been limited to carbon monoxide.

Hourly average meteorological conditions at the airport were also recorded. Meteorological conditions and the level of aircraft activity are determining factors in the carbon monoxide concentrations at specific sites at the airport. Wind speed and direction, atmospheric stability (determined from hourly deviation in wind direction, since hourly temperature gradient data and solar incidence and cloud cover data suggested by Turner[31] were not available), and hour of day (as an indicator of aircraft activity) served as the basis for choosing comparison cases. The ranges of meteorological conditions were divided into sets of intervals. In choosing the meteorological conditions to be used in the initial comparison cases, emphasis was placed on identifying conditions that existed more than once during the control phase of the test program. The need for this constraint was evidenced by the large variation in CO concentrations observed for conditions (both meteorological and aircraft activity) that were identical. Although this limits the amount of usable data, it is necessary to provide meaningful comparisons. The record of meteorological conditions yielded eight cases of conditions that occurred during the same hour on at least three days (see Table 3). Unfortunately, the range of conditions in these eight cases is rather small, with relatively light winds ($\sim$ 3 m/sec) observed for every case and neutral atmospheric stability for every case except one (slightly stable). For six of the eight cases the wind direction was in the interval 280°-310°, and was from 82° for the other two cases. Aircraft activity did, however, vary from high to minimal.

TABLE 3. Meteorological and Activity Conditions for Analyses

Case	Wind Speed (m/sec)	Wind Direction (deg)	Stability Class	Mixing Depth (m)	Hour	Aircraft Activity
	Conditions Used for Regression Analyses					
1	2.9	82	4	100	6	Moderate
2[a]	2.9	82	4	100	7	High
3	2.9	285	4	100	7	High
4[a]	2.9	287	4	290	9	Moderate
5	2.9	300	4	100	2	Low
6	2.9	300	4	290	8	Low
7	2.9	308	4	290	19	Very High
8[a]	2.9	281	5	100	6	Moderate
	Conditions Used for CO Change Analyses					
1	2.9	304	5	100	7	High
2	5.4	315	4	290	11	Very High
3	5.4	304	4	290	15	High
4	2.9	315	5	100	23	Moderate

[a] Cases also used for overlapping analysis of CO changes.

3.2.1 Monitor Site Location

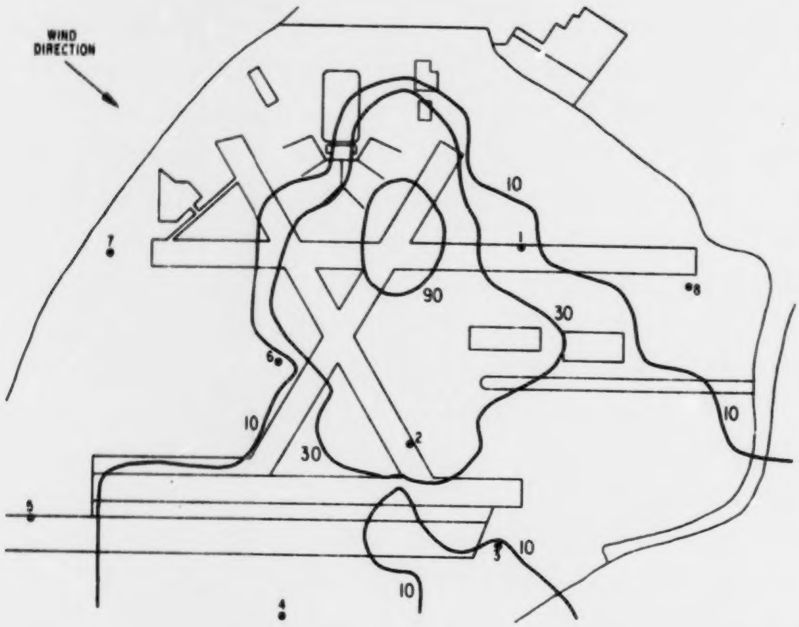
The eight monitoring sites used during the test period are indicated on the map in Fig. 3. Sites were chosen to sample air quality near runways and taxiways where the engine shutdown was anticipated to have an impact; availability of electrical power constrained the specific location of monitors. Siting decisions were made prior to the establishment of the operational protocol of the control phase of the test period. A combination of conservative conditions for the imposition of departure control procedures and fewer periods of adverse meteorological conditions than normal greatly reduced the significance of engine shutdown for outbound aircraft emissions and rendered several of the monitor sites ineffectual for the test.

Isopleths of calculated values of absolute and relative changes in carbon monoxide that result from engine shutdown under the most frequently occurring conditions during the test period are displayed in Fig. 4. The maximum of absolute changes (due to inbound aircraft) occurs just downwind of the concentration of aircraft activity around the airport terminal. Other aircraft operation modes in this same general area that are not affected by control procedures (e.g., engine startup and outbound taxiing) mask the changes, however, and reduce the relative impact of the test. The largest relative changes occur near taxiway G, where inbound taxi emissions are the primary contributor to carbon monoxide concentrations.

It is to be expected that sites upwind of aircraft activity, such as sites 5 and 7 (Fig. 4), will record no changes in carbon monoxide concentrations. Because engine shutdown has been assumed to be effective only for inbound taxiing, some sites that received high levels of aircraft emissions likewise display minimal impact from engine shutdown. Site 8 at the head of runway 26 is the most conspicuous example of the second kind of insensitivity, receiving carbon monoxide principally from aircraft queuing and takeoff. None of the stations sample the region of highest relative change. Site 2 is the most satisfactory of the monitoring sites in this case because both absolute and relative changes are significant there.

3.2.2 Regression Analysis

Calculated carbon monoxide concentrations at each of the GEOMET sites for each of the eight sets of conditions provide 64 calculated values for


WIND DIRECTION
10
1
90
8
30
6
10
2
30
10
5
3
10
10
4
7

a. ABSOLUTE CO REDUCTIONS IN μG/M³, 1-HOUR AVERAGE

b. PERCENTAGE CO REDUCTIONS

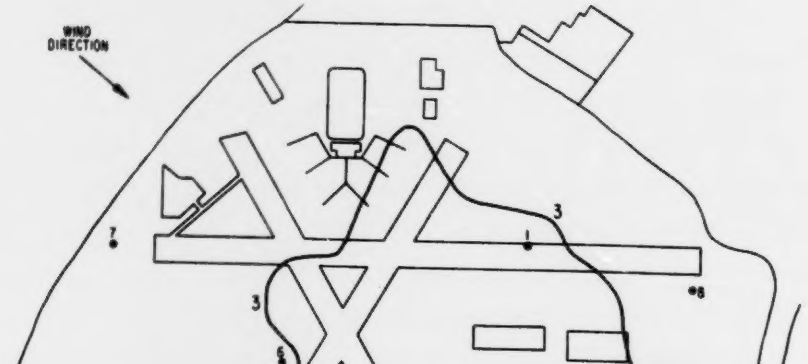

WIND DIRECTION
7
3
1
8
3
6
16
2
3
28
3
5
3
3
16
16
4

Fig. 4. Calculated Changes in CO Concentrations Produced by Amber Test

comparison purposes. Due to the highly divergent nature of the observations under identical conditions, comparisons have been made separately between each calculated value and the several observations that correspond to it. Overall, this has resulted in 180 pairs of calculated and observed values. For most of these pairs, the calculated and observed values are of comparable magnitude. The few cases for which the two values differ greatly (i.e., values for which the ratio, observed value/calculated value, is < .1 or > 15) have been eliminated from the following analysis. Of the ten pairs of values thus eliminated, five are due to exceptionally large observed values for the hour between 5 AM and 6 AM on December 2, 1973 for which the eight observed values range between 1.7 and 3.9 ppm, by far the highest set of observations among the 26 individual hours included in the comparisons. The meteorological and activity conditions for the hour do not seem capable of accounting for such high levels. The five other points eliminated are isolated cases of large disparity between calculated and observed values. At five receptor sites only a single pair of values was eliminated. Two and three pairs of values were rejected at receptors 6 and 1, respectively. None of the 17 pairs of values at receptor 7 exceeded the limits chosen.

A regression analysis was run for the pairs of values associated with each receptor site. The results are shown in Fig. 5 and are summarized in Table 4. It is apparent from the generally small values for the correlation coefficients that for none of the receptor sites is there a strong match between calculated and observed values. The smallest correlation coefficient is for receptor site 1, for which the greatest number of individual pairs of values had been rejected. Even for the remaining pairs, there is evidently little correspondence between observed and calculated values at receptor 1. Although one is not justified in making too strong a case based on the results shown in Fig. 5, the remaining seven receptors appear to divide into two groups based on slopes. Receptors 2 and 6, the more centrally located receptors, have slopes larger than 1.0. The other five receptors are sited near the ends of runways or, as in the case for receptor 4, are rather remote from most airport activity; slopes for these receptors are approximately 0.5 or less. No explanation for this apparent separation on the basis of locational attributes has been discovered, however.

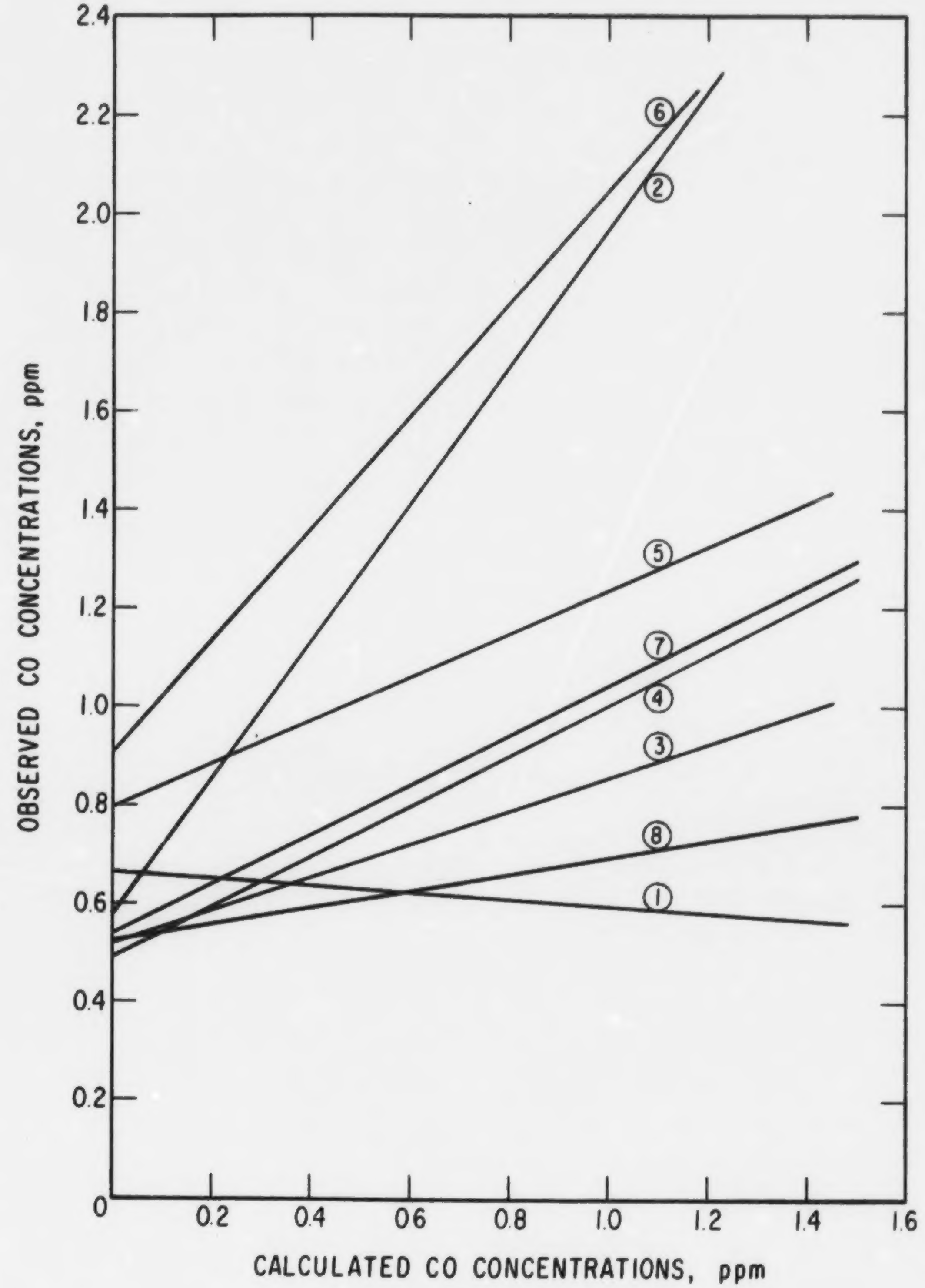


Fig. 5. Regression Lines for Paired Values of Observed and Calculated CO Concentrations

TABLE 4. Results of Regression Analyses with Calculated Concentration Used as the Independent Variable

	Regression Analyses for Individual Receptors			
Receptor	Number of Data Points	Slope	Intercept (PPM)	Correlation Coefficient
1	19	-.07	.66	-.05
2	20	1.39	.58	.40
3	25	.34	.52	.12
4	20	.51	.49	.22
5	23	.44	.80	.20
6	22	1.14	.90	.32
7	17	.50	.54	.35
8	24	.17	.53	.23

	Regression Analyses for Grouped Receptors			
Group	Number of Data Points	Slope	Intercept	Correlation Coefficient
All	170	.14	.75	.08
2,6	42	1.09	.81	.32
3,4,5,7,8	109	.22	.62	.19

Results of regression analyses of the data for combinations of receptors are also given in Table 4. When all 170 points are combined, the correlation coefficient is quite small. For the two groupings of receptors evident in Fig. 5 (i.e., receptors 2 and 6; and receptors 3, 4, 5, 7, and 8), regression analyses yield somewhat improved correlation coefficients and distinctly different slopes. These results can be interpreted in the following way. The model is, in general, underpredicting CO concentrations. Regression intercepts between .6 and .8 ppm would indicate an unaccounted-for background CO level; a value of this magnitude is perhaps not an unreasonable estimate of the levels of CO in the air masses advected into the region. Closeness of the slope to 1.0 would be a good indication that the model is doing a respectable job in predicting changes in concentration with spatial and meteorological changes. On the basis of this criterion the modeling of conditions affecting receptors 2 and 6 appears to be more satisfactory than is the case for the other receptors. As stated above, the cause for this difference among the results at the various receptors is unclear. Tests for statistical significance indicated that only receptors 2 and 6 are statistically significant at the .15 level. (Only receptor 2 is significant at the .1 level.) All other individual receptors and the cumulative grouping of all the receptors showed no statistical significance even at the .15 level.

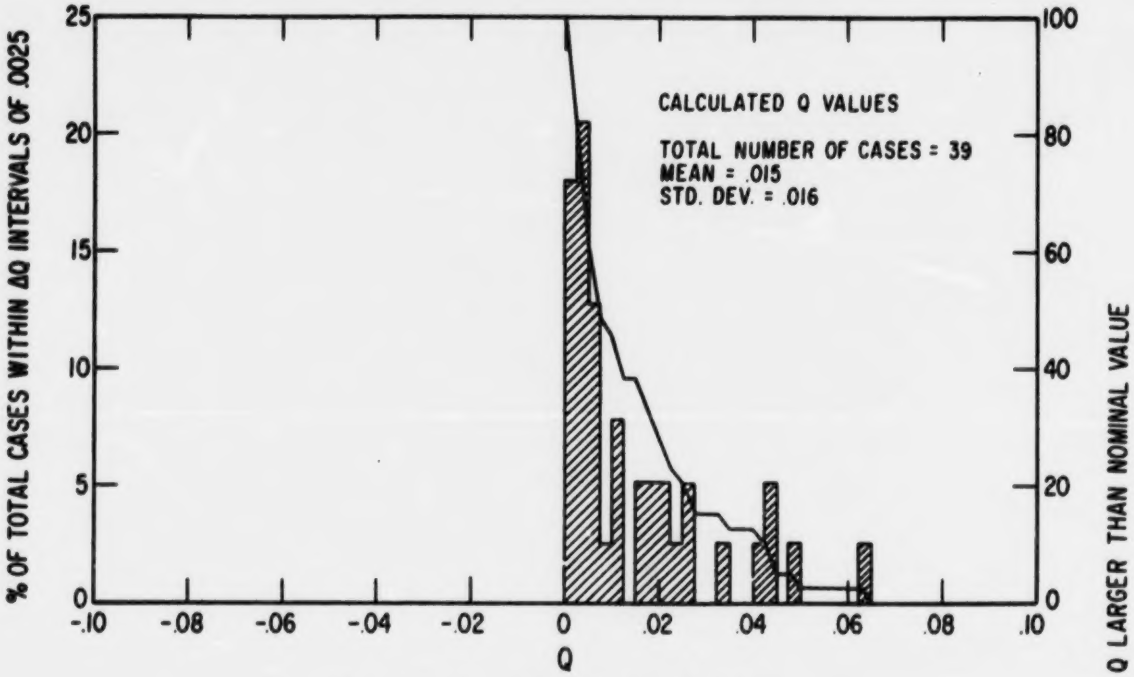
3.2.3 Overlapping Conditions

A further basis for comparison between observations during the test period and the results of model calculations is provided by the relative changes in carbon monoxide concentrations at receptor sites between baseline and control phases of the test. To examine the change in air quality at a specific site requires that all conditions except those associated with the test program be identical. The GEOMET record of hourly meteorological conditions at the airport was reexamined to identify cases of identical conditions (including activity hour) in the two test phases. Such overlapping conditions do not necessarily occur for the eight cases, taken just from the control phase of the program, that provided the data for the preceding regression analysis. Seven cases of conditions which existed during both baseline and control phases of the test and occurred at least twice in one of the phases were used for the analysis of relative changes. As shown by the summary of these seven sets of conditions in Table 3, the wind direction is from the northwest in six of the cases, indicating once again the high frequency of northwest winds during the test period.

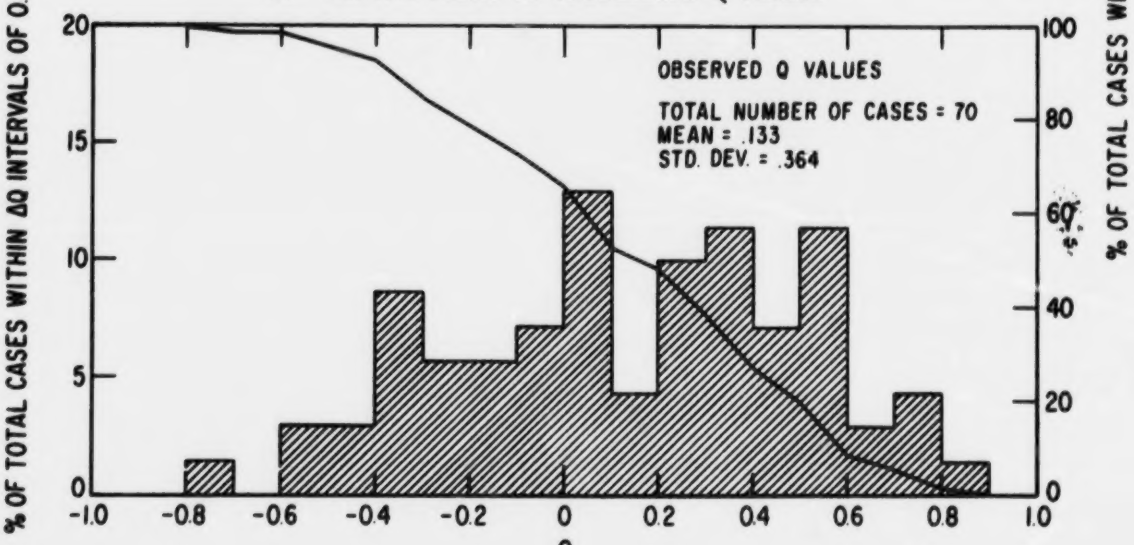
The quantity chosen to display the relative changes between the test phases is Q = (B-A)/(B+A), where B and A are the hourly averaged carbon monoxide concentrations for baseline and Amber Test control phase conditions, respectively. Mathematically, this quantity ranges between -1.0 and +1.0. For modeled concentrations the value is positive at sites affected by inbound aircraft activity and is equal to 0 otherwise. The distribution of non-zero Q values from model calculations (39 of 56 calculated receptor values) is shown in Fig. 6.a. The mean of the distribution is 0.015 which implies an average relative change between test phases of approximately 3%. Monitored CO concentrations under identical conditions produce a distribution of Q values that is shown in Fig. 6.b. It was not uncommon for measured concentrations to be higher during the control phase than for identical circumstances during the baseline phase, causing negative Q values. The preponderance of values is non-negative, however, and the mean value of .133 indicates a relative reduction between baseline and control phases of 23.5%.

To test whether there is a significant difference between the observed and the calculated values for Q, the pair of observed and calculated Qs for each receptor and met set combination was considered. Because the seven met sets were chosen to have occurred at least twice in one of the test phases, more than one value of observed Q is possible for a specific receptor and met set combination. It is also true, however, that data are missing for some of the receptors on the hours chosen. The net result is that 99 pairs of observed and calculated Q values are usable. Each pair represents an independent trial of the comparison of observed and calculated Q. One of the simplest statistical tests based on these trials is the sign test in which numbers of occurrences of positive and negative differences (observed minus calculated) are determined. Although some loss of information results from this categorization to a dichotomous variable, it will be shown that even this simple test retains enough sensitivity in the present case. Pairs for which there is no difference between observed and calculated Q values (4 of 99 values) were eliminated from the analysis. The null hypothesis that observed and calculated Q values are indistinguishable implies that positive and negative differences should be equally likely to occur. For the occurrence of positive differences to be

Q = (B-A)/(B+A)



a. Distribution of Calculated Q Values



b. Distribution of Observed Q Values

Fig. 6. Distributions of Calculated and Observed Values for the Measure of Change in CO Concentrations

statistically significant at the .05 level requires that a positive difference be found in at least 56 of the pairs. Positive differences actually occur in 58 of the 95 pairs. It can therefore be said that, at the .05 level of significance, an observed value of Q will be greater than the corresponding calculated value. By dichotomizing the differences, we have sacrificed the possibility of being able to say by how much the observed value might be expected to exceed the calculated one.

In the GEOMET report of analyses of the entire quantity of observed data, it is noted that measurements during the control phase are less than baseline measurements by from 14% to 38%, depending on the assumed meteorological basis used for comparison. These are uncorrelated comparisons with no attempt made to match identical hours between the two phases. All attempts to associate these changes with the control procedures proved unsuccessful, however. The changes for hours when the procedures should have had relatively little impact because of the low level of arrival activity were found to be indistinguishably different from those for hours dominated by arrival activity; changes of approximately 20% were pervasive. The suggestion is made that the measured difference might in fact be due to a curtailment of automotive traffic on peripheral highways due to the increasing shortage of gasoline over the test period. There is evidence from the record of carbon monoxide measurements taken by the Georgia Department of Natural Resources at its long-term monitoring site in downtown Atlanta that a decrease in concentrations between November and December might have been regionwide. When 24-hour averaged values of carbon monoxide levels in downtown Atlanta for the last two weeks in November and for the first two weeks in December are compared, the December values are found to average 33% lower than the November ones. Whatever the cause of this decrease, it is very possible that it has obscured the monitored evaluation of the test procedures.

3.2.4 Validation Implications

Based on the above validation analysis, it must be said that the model does not correlate with the observed data as well as would be desired. Several explanations for the discrepancy can be offered. First, the emission inventory used in the model cannot be made to exactly replicate the actual emission pattern within the bounds of reasonable resource expenditure. This is especially true with regard to the environ emission inventory. The whole modeling concept relies on the simulations of average conditions wherein transient variations are obscured. In the field test program there was an insufficient amount of data collected to satisfy the "average condition" requirements. All participants in the program recognized the problems of the short test period but insufficient resources were available to correct the situation. In conjunction with this problem, the unfortunate coincidence of the national fuel shortage in the middle of the test program introduced another perturbation that could not be simulated with the available data. As was previously discussed, the fuel shortage may have contributed to the large (33%) reduction in CO concentrations observed at the Georgia Department of Natural Resources monitoring sites. The unusual behavior of the observed Q distribution (Fig. 6.b.) indicates the possible scope of the problem.

A second possible explanation for the discrepancies is the rather narrow range of CO concentrations observed as well as the small absolute concentrations (all less than 2.5 ppm from Fig. 5). Measurements are difficult in this range and small equipment problems can result in substantial errors in the data.

In addition to the data problems, the model itself appears to be underpredicting CO concentrations. The relatively large intercepts of the regression lines indicate an unaccounted-for background level. This level is of the same order of magnitude as the absolute values and hence represents a significant portion of the actual concentration.

Despite the rather weak validation here, the model has been shown in other cases.[9,10] to do a respectable job in describing temporal and spatial changes in air quality. The justification for its use in the following analyses is predicated, then, primarily on the previous validation results rather than on those available from the field test program, which are, at best, inconclusive. Interpretation of the results must, therefore, be made with this caveat in mind.

Although it would be desirable to establish confidence limits on the model calculations, this cannot be done here because of the uncertainties in the observed data. Rather, it can be said that the relative changes in calculated air quality effected by each control strategy will probably be a reasonable estimate of what might be expected in practice. Additional validation work would be necessary to support a stronger statement about the accuracy of the calculations.

4.0 CONTROL STRATEGIES

4.1 BASELINE CONDITIONS

In the following analyses the baseline conditions against which the various control strategies are evaluated are taken to be those existing in the initial weeks of the field test program. Normal operating procedures at the Atlanta airport are assumed and air traffic volume and fleet mix as observed in late 1973 are used as the reference values; Table 5 gives this pattern. Runway use is assigned on the basis of wind direction with traffic being split between the northern runway (8/26) and the southern runways (9L/27R, 9R/27L) in the ratio of 60/40. The northern runway is preferred because of its proximity to the terminal. Aircraft ground taxi paths and taxi speeds were those observed during the field test.

4.2 ENGINE SHUTDOWN

This strategy is designed to reduce carbon monoxide and hydrocarbon emissions during aircraft taxi/idle operation. Since a large fraction of the aircraft's emissions of these pollutants occurs during taxi/idle, the strategy offers promise of significant overall emission reduction. As was demonstrated at the Atlanta airport, the procedure can be implemented at an existing airport with a minimum of effort and no additional expenditures. (In fact, the resulting fuel conservation is a cost saving.)

The engine shutdown strategy evaluated here is the same as that employed at the Atlanta airport during the field test. The strategy achieves emission reductions in two ways. First, the operation of fewer engines reduces the overall aircraft emission rate; second, the operation of the remaining engines at higher power settings (to maintain taxi speed) moves them closer to their maximum performance design conditions and hence reduces the engine emission rate. Both of these conditions were simulated in the AVAP model.

Five of the aircraft types included in the model participated in the engine shutdown test (Amber Test) either inbound or outbound as was shown on Table 1 (DC-8 and B-707 aircraft were modeled as a single type). The model contained two tables for the number of engines used by each aircraft. For the description of Amber Test procedures, the first table was filled with the total number of engines on each aircraft and the second contained the number of en-

TABLE 5. Temporal Distribution of Aircraft at the Atlanta Airport

		Diurnal Pattern (% of daily total)											
		Hour											
Aircraft Type	Annual LTOs	1	2	3	4	5	6	7	8	9	10	11	12
DC-9	99,155	4.3	1.3		.2	1.2	4.5	3.7	1.6	4.7	4.1	5.7	6.6
B-727	75,190	5.2	2.0	.9	1.0	2.0	4.5	4.5	.9	3.0	5.5	6.2	8.2
DC-8	24,820	6.4			.7		4.3	7.1		.7	6.4	9.3	5.0
MR-404	8,395							2.1		8.3	8.3	12.5	8.3
CV-880	5,110							13.6			4.5	22.7	1.5
Be-99	16,495									8.6	8.6		14.3
YS-11	5,240		3.4					3.4	6.9		6.9	6.9	3.4
B-737	7,665							1.9	5.8		9.6	11.5	5.8
B-747	2,555						14.3	14.3				7.1	
L-1011	1,460						7.7	7.7		7.7	7.7		
DC-10	730	20.0						20.0				20.0	
GA-Jet	8,365	1.7	3.6	7.8	5.4	2.2	1.5	1.2	1.6	3.1	4.7	5.2	5.5
GA-Pist.	5,975	1.7	3.6	7.8	5.4	2.2	1.5	1.2	1.6	3.1	4.7	5.2	5.5
Total	252,755												

		Diurnal Pattern (% of daily total)												
		Hour												
Aircraft Type	Annual LTOs	13	14	15	16	17	18	19	20	21	22	23	24	Weekday/Weekend
DC-9	99,155	6.3	4.0	6.9	6.5	4.3	4.0	4.9	6.1	5.7	4.7	3.7	5.1	.143/.143
B-727	75,190	4.8	2.7	4.0	5.5	4.5	5.5	6.5	4.7	7.0	3.0	2.2	5.5	.143/.143
DC-8	24,820	5.7		.7	7.9	5.7	5.0	7.1	10.0	5.0	1.4		7.1	.143/.143
MR-404	8,395	2.1	4.2	4.2	4.2	6.2	6.2	6.2	8.3	12.5		4.2	2.1	.143/.143
CV-880	5,110	4.5		4.5	18.2	9.1				9.1	4.5		4.5	.143/.143
Be-99	16,495	2.9	5.7	14.3	8.6	2.9	17.1	2.9	11.4	2.9				.143/.143
YS-11	5,240	6.9	3.4		3.4	10.3	10.3	6.9	6.9	3.4	10.3	6.9		.143/.143
B-737	7,665	1.9	9.6	9.6	3.8	5.8	7.7	3.8	9.6	3.8	1.9	3.8	3.8	.143/.143
B-747	2,555				7.1	14.3	7.1	7.1	14.3	7.1			7.1	.143/.143
L-1011	1,460			7.7	7.7			15.4	7.7		7.7	7.7	15.4	.143/.143
DC-10	730								20.0				20.0	.143/.143
GA-Jet	8,365	5.0	5.2	7.0	6.0	6.7	7.2	5.4	4.6	3.4	3.6	2.6	1.7	.161/.098
GA-Pist.	5,975	5.0	5.2	7.0	6.0	6.7	7.2	5.4	4.6	3.4	3.6	2.6	1.7	.161/.098
Total	252,755													

gines used during the application of the control strategy. The model associated the use of one or the other of the engine number tables separately with each taxiway segment and provided for a different choice for inbound and outbound taxiing for each segment. A further consideration was required to treat the fact that the effect of control procedures is not uniform among the participating aircraft: DC-9s participated only outbound, DC-8s and CV-880s participated only inbound, and B-727s and DC-10s participated both inbound and outbound. This aspect was handled by overriding the use of the control phase engine number table for inbound DC-9s and for outbound DC-8s and CV-880s and forcing the normal table to be used in those circumstances.

Outbound engine shutdown was modeled only over that portion of the taxi path between the designated shutdown and restart points (see Fig. 3 and accompanying text). Outbound controls were seldom activated, because few periods of excessively long delay were encountered during the test program. In the model's queuing simulation, the aircraft queue length, averaged over an hour, was not long enough under the normal range of conditions to extend onto the controlled portion of the taxi path. For most of the computer runs, therefore, outbound engine controls were not used. In one set of runs, however, with assumed worst case meteorological conditions and four times normal queuing length, outbound reduced engine operation was modeled for both taxiing and queuing emissions.

The change in engine pollutant emission rates accompanying the slightly higher power setting of the remaining operating engines was simulated by assuming that the thrust would be increased linearly. For a two-engine aircraft (e.g. DC-9), the power setting on controlled taxi segments for the one operating engine would be 100 percent higher than for normal taxiing. Although the percentage change in power setting is large for all aircraft participating in Amber Test, the absolute change represents only a small portion of the full range of engine power settings. Linear approximations to the emission rate vs. power setting curves are justified over this small range and were used as the basis of the emission rate change modifications added to the model.

The JT8D engine used on DC-9, B-727, and B-737 aircraft can be used as an example of the modifications made to simulate engine shutdown. The degree of participation is different for each of these aircraft as indicated in

Table 6, which also lists the number of engines per aircraft (from the first engine number table in the model) and the number of engines operating during the control phase of Amber Test (from the second engine number table in the model). Emission rate curves for the JT8D engine are displayed on Fig. 7; these curves were generated from the emission rates at the four engine mode settings which are related to fractions of full engine power for the purposes of these curves. Under baseline conditions the engines on all three aircraft types were operated at 6% of full power with a carbon monoxide emission rate of 15.2 kg/hr for taxiing as shown on Table 6.

TABLE 6. Comparison of the Effects of Engine Shutdown on the Carbon Monoxide Emission Rates of Three Aircraft Types Using JT8D Engines

	Aircraft Type		
	DC-9	B-727	B-737
Degree of participation in Amber Test	Departures only	Arrivals and departures	Exempt
Number of engines	2	3	2
Taxi emission rate per engine during baseline conditions	15.2 kg/hr	15.2 kg/hr	15.2 kg/hr
Taxi emission rate per aircraft during baseline conditions	30.4 kg/hr	45.6 kg/hr	30.4 kg/hr
Engines operating on controlled taxi segments during engine shutdown strategy	1	2	2
Taxi emission rate per engine on controlled taxi segments	13.5 kg/hr	14.4 kg/hr	15.2 kg/hr
Taxi emission rate per aircraft during engine shutdown	13.5 kg/hr	28.8 kg/hr	30.4 kg/hr

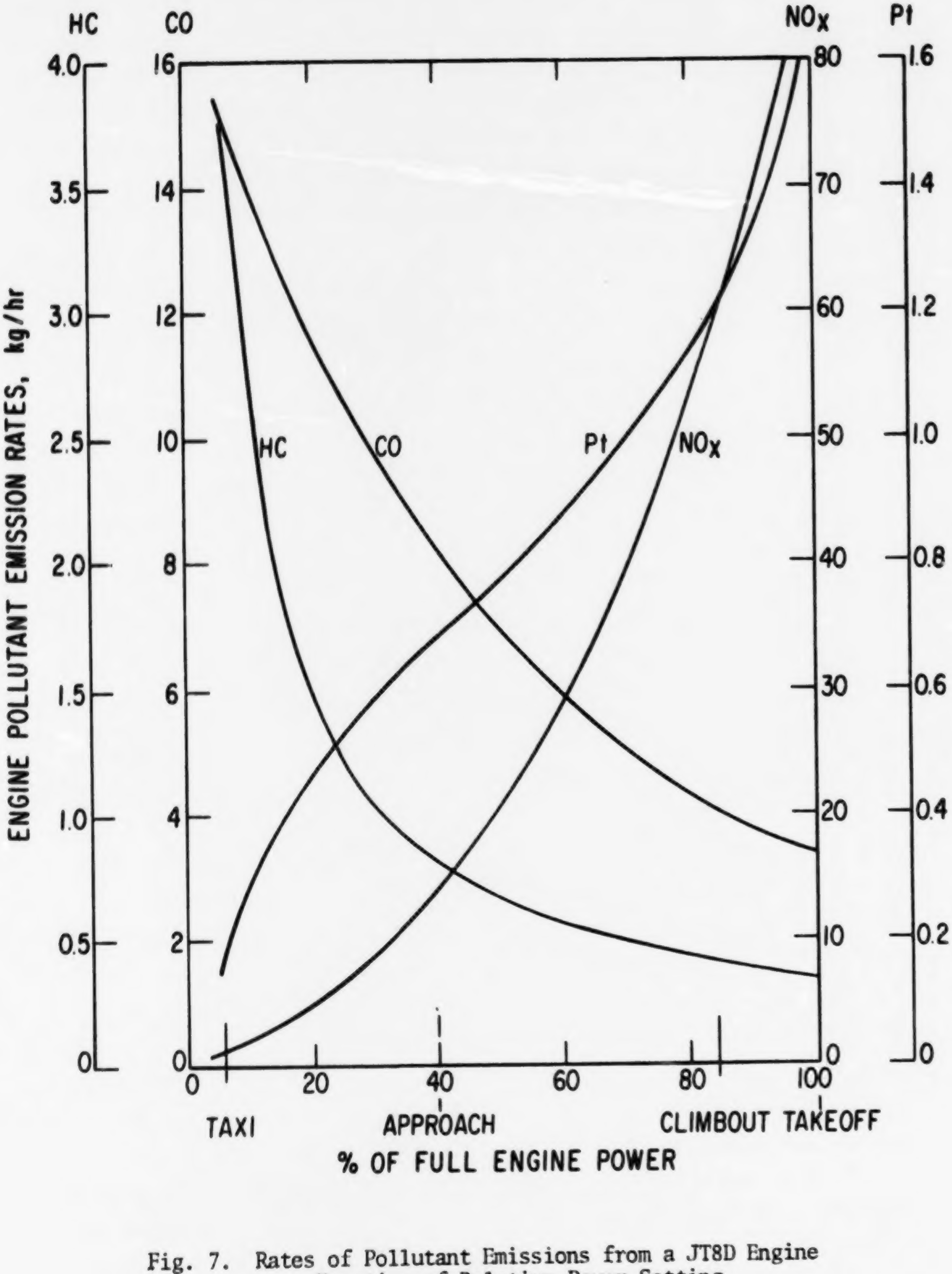


Fig. 7. Rates of Pollutant Emissions from a JT8D Engine as a Function of Relative Power Setting

On arrival taxiways during the engine shutdown phase of the program, JT8D engine operation was changed for only the B-727 aircraft, which shut down one engine after leaving the arrival runway. Segments of arrival taxiways between the runway turnoff points and the terminal parking areas were, therefore, modeled to use only 2 engines for the B-727. A straight-line approximation to the carbon monoxide emission rate curve in the vicinity of the engine power setting for taxiing shows that a 50% increase in power for the two operating engines on inbound B-727s results in a decrease in the engine emission rate to 14.4 kg/hr. On arrival taxiways the DC-9 and B-737 aircraft are modeled as operating with their full complement of engines at the normal 6% power setting.

The simulation of the engine shutdown strategy for departures affected only the intermediate segments of departure taxiways. For these segments DC-9s and B-727s operated with one less engine, and the engine number values shown on Table 6 are effective in the model. The increase of 100 percent in power for the remaining operating DC-9 engines results in a carbon monoxide emission rate decrease to 13.5 kg/hr, based on the linear approximation of Fig. 7. Aircraft emission rates on the controlled segments of outbound taxiways, therefore, are reduced to 13.5 kg/hr for DC-9 and 28.8 kg/hr for B-727 aircraft. The B-737 emission rate is unchanged as are the rates for all other portions of the outbound taxiways.

In a similar fashion, the modified emission rates were developed for all aircraft participating in the test as shown in Table 7.

4.3 AIRCRAFT TOWING

This strategy was suggested by EPA[2,4] as a means of reducing a substantial portion of the taxi/idle emissions by having aircraft towed between the duty runway and the terminal by a tractor. Although emissions could be substantially reduced by implementation of this technique, it presents some operational problems that would foreclose immediate application at existing airports. In order to avoid air traffic delays, the towing vehicle would have to maintain the same taxi speed as normally operating aircraft (about 40 km/hr with no impediments). Nose wheel gear on most aircraft are not designed for the extended horizontal loading that would result and would require structural reinforcement. Some aircraft are equipped with fuselage-mounted towing

TABLE 7. Taxi/Idle Emission Rates for Aircraft Participating in Engine Shutdown Test

	Emission Rate (kg/hr)				
	DC-9	B-727	DC-8	CV-880	DC-10
Engine Type	JT8D	JT8D	JT3D	CJ805	CF6
Number of Engines	2	3	4	4	3
Normal Taxi/Idle Emission Rates					
CO	30.40	45.60	197.60	115.60	70.50
HC	7.42	11.13	178.80	49.60	21.00
NO_x	2.64	3.96	2.60	2.85	4.89
Number of Engines in Use During Participation in Shutdown Strategy	1	2	3	3	2
Modified Taxi/Idle Emission Rate					
CO	13.55	28.76	140.37	85.44	42.98
HC	2.45	6.16	119.10	33.99	11.72
NO_x	2.77	4.08	2.95	2.79	8.14

hooks, but special equipment would have to be designed to make regular use of them. There are numerous safety complications that must also be considered. Despite the operational problems, the strategy offers some interesting possibilities for emission reduction and so is evaluated here.

In the model simulation, departing aircraft are towed from the terminal gate to the end of the duty runway. Engines are started just prior to positioning for takeoff. For arriving aircraft it is assumed that all engines are shut down after clearing the arrival runway. The strategy is applied to turbine engine aircraft only.

To simulate the emissions of the towing vehicle, the aircraft taxi-idle emission factor was replaced by the tractor's emission factor. Table 8 compares the tractor emission rate to that of the aircraft. It can be seen that the use of the tow tractor reduces the emission rates by at least an order of magnitude in all cases.

TABLE 8. Comparison of Tow Tractor and Aircraft Taxi-Idle Emission Rates

	Pollutant Emission Rate (kg/hr)			
	CO	HC	NO_x	Pt
Tow Tractor	1.92	.30	.13	.02
DC-9	30.40	7.42	2.64	.32
B-727	45.60	11.13	3.96	.48
DC-8	197.60	178.80	2.60	.80
CV-880	115.60	49.60	2.86	2.36
B-747	185.20	49.60	11.00	4.00
DC-10	70.50	21.00	4.89	.06

4.4 CAPACITY CONTROL

The capacity control strategy relies on the reduction of overall aircraft activity by increasing the passenger load factors. By imposing the requirement for increased utilization of available seats, fewer aircraft would be required to transport the same number of people.

It would be unrealistic to assume that this strategy could be imposed at a single airport without consideration of the national picture. The complex nature of the route structure would require a detailed analysis of the implications of fewer available seats on the economic status and quality of service of the airlines. The strategy is evaluated here as a consideration of what the impact of a national policy to reduce aircraft activity by increasing passenger load factors would be at the Atlanta airport.

The parametric load factor used to define this strategy is the ratio of the number of occupied seats to the number of available seats. Based on questionnaire data, the load factor at the Atlanta airport varied between 48% and 64% among the airlines for the period of late 1973. The overall average load factor was 62%. The strategy, as studied here, involved the reduction of the number of air carrier flights while maintaining the fleet mix distribution constant. General aviation activity was unchanged. Model runs were made with load factors of 65% and 70%. Higher load factors were not used because it was anticipated that they would have serious effects on the quality of service. Table 9 gives the aircraft activity for each load factor. It can be seen that overall activity is reduced by about 4% and 12% by increasing the load factor to 65% and 70%, respectively.

TABLE 9. Aircraft Activity with Varying Load Factors

Aircraft Type	Aircraft Activity (LTOs/year)		
	Baseline Load Factor 62%	Load Factor 65%	Load Factor 70%
DC-9	90,155	86,008	79,877
B-727	75,190	71,731	66,618
DC-8	24,820	23,678	21,990
CV-880	5,110	4,875	4,526
B-737	7,665	7,312	6,791
B-747	2,555	2,437	2,280
L-1011	1,460	1,393	1,294
DC-10	730	696	647
BE-99	16,495	15,736	14,615
MR-404	8,395	8,009	7,438
YS-11	5,840	5,571	5,174
Gen. Av. - Jet	8,365	8,365	8,365
Gen. Av. - Piston	5,975	5,975	5,975
Total	252,755	241,786	225,590

4.5 FLEET MIX CONTROL

The report on the initial phase of this program[1] indicated that the trend toward the newer wide-body aircraft would result in lower per-passenger emissions at the study airport (St. Louis in that case). The fleet mix strategy studied here was designed to evaluate the impact that an acceleration of that trend might have at the Atlanta airport. As with the capacity control strategy, it is not possible to consider the imposition of this control measure at a single airport; national route requirements must be evaluated.

To simulate the strategy it was assumed that the same number of air carrier seats would be available as under baseline conditions. The fleet mix forecasted for the Atlanta airport in 1980[13] was used to generate the aircraft activity pattern. General aviation activity was unchanged. Table 10 compares the new fleet mix to baseline conditions.

TABLE 10. Fleet Mix Change

	Fraction of Total Aircraft Activity	
Aircraft	Baseline	Fleet Mix Strategy
DC-9	.357	.333
B-727	.298	.230
DC-8	.098	0
CV-880	.020	0
B-737	.030	.042
B-747	.010	.081
L-1011	.006	.082
DC-10	.003	.081
Be-99	.065	.053
MR-404	.033	0
YS-11	.023	.021
Gen. Av. - Jet	.033	.045
Gen. Av. - Piston	.024	.032
	1.000	1.000
Total Activity (LTOs/year)	252,755	187,880

It is immediately evident that there is a large reduction in total activity (25.7%) as a result of retaining the same number of available seats. It is not clear that this would be a workable situation from the standpoint of route scheduling and the implementation of a fleet mix change would most likely result in an increase in available seats with a correspondingly lower load factor. An analysis of the national picture would reveal the actual impact of this strategy on activity. The impact on air quality as studied here, therefore, represents an upper bound on the emission reduction achievable through this procedure.

It should also be noticed that DC-8 and CV-880 aircraft are removed from the fleet. These emissions will have a significant impact on emissions as will be shown later.

4.6 ENGINE EMISSION STANDARDS

The final strategy studied here is the application of the federal emission standards for aircraft.[5] The strategy is evaluated in two ways. First, the standards are assumed to apply to all aircraft currently using the Atlanta airport and the fleet mix and activity level are assumed to remain at their current situation. This will give an indication of the impact of the standards over existing conditions. Second, the standards are applied to the projected aircraft activity for 1990. Since the standards go into effect in 1979, it is assumed that virtually all aircraft will meet the standards by 1990. This will give an evaluation of the air quality impacts of the application of the emission standards and of the growth in air traffic at Atlanta.

The federal emission limits are given on Table 11. Note that the T2 turbine engine class has two applicable standards, one to be in effect in 1979 and one in 1981. The 1981 standard applies only to new technology engines which will be certified in that time frame. For the purposes of this analysis, only the 1979 standards are used, the rationale being that a newly certified engine would probably be fitted on to a new aircraft type. Only current generation aircraft were included in the air traffic forecasts for Atlanta.[13] The strategy analysis, therefore, represents a conservative estimate of the emission reductions that might be achievable through application of the standards.

The test cycle on which the emission limits are based are given on Table 12. To apply the standards to the modal emission rates that are used in the AVAP model it is necessary to normalize the emission change with respect

TABLE 11. Federal Aircraft Emission Standards

Engine Type	Typical Aircraft	Emission Limit[a]		
		CO	HC	NO_x
Turbine				
T1 (<8000 lbs thrust)	YS-11, Gen. Av.-Jet	9.4	1.6	3.7
T2 (>8000 lbs thrust)	B-747, L-1011, DC-10	4.3[b] 3.0[c]	0.8[b] 0.4[c]	3.0[b] 3.0[c]
T3 (all JT3D engines)	DC-8, CV-880	4.3	0.8	3.0
T4 (all JT8D engines)	DC-9, B-727, B-737	4.3	0.8	3.0
P2 (turboprop)	Be-99	26.8	4.9	12.9
Piston				
P1 (all)	MR-404, Gen. Av.-Piston	42.0	1.9	1.5

[a] For turbine engines, units are in (lbs/1000 lbs thrust-hr/cycle), for piston engines in (lbs/1000 rated hp/cycle).

[b] Standard applicable to new manufactured engines after January 1, 1979.

[c] Standard applicable to new certified engines after January 1, 1981 (i.e., new technology engines that will be developed for service).

to the test cycle. To do this, the emissions from current engines[14] run over the federal test cycle are computed (in lbs/1000 lbs thrust-hour or lbs/1000 rated hp as appropriate). An emission reduction ratio is formed by comparing the computed emissions to the allowable emissions. This reduction ratio is then applied to all of the modal emission rates to obtain emission factors that are in compliance with the standards. There is an assumption in this method which implies that, in meeting the federal limits, the emission rates from every operating mode will be decreased by the same amount. In practice this may not be exactly true. Engine design modifications may result in a much lower emission rate in one mode (e.g., taxi/idle) and an unchanged emission rate in another mode (e.g., approach). Lacking any experimental test data, the assumption of uniform reductions is a reasonable first approximation. Table 13 gives the new emission factors and the computed emission reduction factor. It can be seen that the standards are providing the largest reductions in emissions of CO and hydrocarbons with somewhat smaller reductions in NO_x.

TABLE 12. Test Cycle for Aircraft Emission Standards

	Time in Mode (minutes)		
Mode	T1, P2	T2, T3, T4	P1
Taxi/idle (out)	19.0	19.0	12.0
Takeoff	0.5	0.7	0.3
Climbout	2.5	2.2	5.0
Approach	4.5	4.0	6.0
Taxi/idle (in)	7.0	7.0	4.0

4.7 OTHER STRATEGIES

There are several other emission reduction strategies, which might be considered for airport air quality control but which were not studied. These include remote parking of aircraft and the use of passenger transport buses to minimize taxi time, gate hold procedures wherein aircraft are not cleared to start engines until departure delays fall below specified times, and increased engine speed during taxi to improve operating performance. In addition to the controls applied to aircraft, there are some strategies that could

TABLE 13. Modified Aircraft Emission Factors In Compliance with Federal Regulations[a]

Engine	Class	Pollutant	Mode				Emission Reduction Ratio
			Taxi/Idle	Approach	Climbout	Takeoff	
P&W JT9D	T2	CO	18.00	5.74	2.06	1.45	.388
		HC	12.47	.38	.34	.37	.279
		NO_x	1.11	9.89	84.00	132.10	.404
GE CJ805	T2	CO	3.84	2.58	1.74	.29	.133
		HC	.81	.07	.02	.02	.065
		NO_x	.35	4.00	16.70	24.90	.496
GE CF6	T2	CO	17.86	6.41	2.27	2.31	.760
		HC	3.46	.43	.29	.29	.494
		NO_x	.65	31.20	60.10	97.50	.398
P&W JT3D	T3	CO	6.42	2.34	.90	.73	.130
		HC	3.04	.24	.15	.14	.068
		NO_x	.40	6.15	27.10	41.70	.622
P&W JT8D	T4	CO	5.56	3.02	1.47	1.24	.366
		HC	1.10	.23	.12	.10	.297
		NO_x	.52	5.53	3.50	35.50	.395
GE CJ610	T1	CO	2.28	.83	[illegible]	.26	.072
		HC	.41	.03	[illegible]	.02	.057
		NO_x	.08	1.21	.34	8.22	.204
All T56-A7	P2	CO	6.94	1.66	1.37	.98	1.000[b]
		HC	1.53	.12	.11	.10	.523
		NO_x	.98	3.53	9.62	10.40	1.000[b]
Tel 0-302	P1	CO	.37	.81	2.21	2.38	.074
		HC	1.83	.22	.15	.15	.261
		NO_x	1.16	5.60	107.80	174.90	.714
Tel 2800	P1	CO	71.90	157.00	426.00	460.00	1.000[b]
		HC	.35	.49	1.29	1.47	.388
		NO_x	.03	.10	.74	.42	1.000[b]

[a] Based on uniform emission reduction in each mode.

[b] Current emissions are meeting standards.

be applied to other airport sources. Minimizing motor vehicle traffic through the use of a mass-transit access system, emission controls on ground service vehicles, and modifications to the fuel storage and handling routines might be possible options.

For some airports, induced commercial and industrial development in the airport vicinity may play a contributing role to air quality degradation. Land use controls, which in most cases are necessary to minimize noise impacts, may provide some relief from concentrated air pollutant emission densities also. This is discussed in more detail in Section 8.0.

5.0 STRATEGY IMPACT ON AIRPORT AIR QUALITY

This section will deal with the effectiveness of each of the strategies on air quality in the airport proper. In using the AVAP model to perform these assessments, the validation results and the caveats discussed in Section 3.0 must be kept in mind.

5.1 EMISSION PATTERN

Table 14 gives the emissions for the Atlanta airport and its environs under baseline conditions. Environ emissions included all point sources in the ten-county area surrounding the airport and area sources extending 20 km from the airport boundary. A more detailed description of the environ inventory is given in Sections 6.0 and 7.0.

TABLE 14. Annual Emissions for Atlanta Airport and Environs Under Baseline Conditions

Source	Annual Emissions (metric tons/yr) CO	 HC	 NO_x
Aircraft	4,959	2,415	2,072
Ground Service Vehicles	1,626	224	57
Access Traffic	1,870	430	212
Engine Test	130	51	284
Fuel Storage	0	375	0
Space Heating	6	2	29
Airport (non-aircraft)	3,632	1,082	582
Total Airport	8,591	3,497	2,654
Environs[a]	264,000	77,000	65,700

[a] Includes all point sources in Fulton, Clayton, DeKalb, Fayette, Henry, Spalding, Gwinett, Rockdale, Cobb, and Coweta Counties and area sources to a distance of 20 km from the airport boundaries.

Aircraft are responsible for about 58% of the CO, 69% of the HC, and 78% of the NO_x at the Atlanta airport. The entire airport accounts for 3% of the regional CO emissions, 4.5% of the HC, and 4% of the NO_x. The indications are that the control of aircraft emissions will have a small impact on regional emission loads. It is important to emphasize that any controls applied to aircraft have their impact diminished by the amount of the relative contribution of aircraft to the total emission rate. In the case of the Atlanta airport, for example, any reduction in aircraft CO emissions becomes only 58% as large in total airport emission reduction and 1.74% (58% x 3%) as large for regional emission reduction. The expected impact of a strategy, therefore, must be put into perspective with the total emission picture. Table 15 compares the emission reduction impact of each strategy in terms of the relative change in aircraft and total airport emissions.

It is obvious from Table 15 that the application of engine emission standards has the greatest impact on reducing emissions. In addition to providing large reductions in CO and HC emission rates, the standards provide substantial reductions in NO_x that cannot be matched by the other control options. Aircraft towing and the fleet mix change are next in order of achievable emission reductions, but the fleet mix option has the drawback of significantly increasing NO_x emissions. The engine shutdown and capacity control strategies provide only small reductions and the indications are that these procedures may be justified only in regions requiring maximum emission control from all sources.

It is also evident from Table 15 that the best strategy provides, for the entire airport, a little more than a one-third reduction in CO emissions and about a one-half reduction in HC and NO_x emissions, corresponding to 62%, 71%, and 45% reductions in aircraft emissions of these pollutants, respectively. For the capacity control and fleet mix control techniques there is a synergistic effect since changes in the aircraft activity pattern also change the ground service vehicle requirements. Reductions in aircraft emissions by reducing the total aircraft activity has an added benefit through reduction in ground service vehicle emissions.

Table 16 summarizes the fractional contribution of each mode of aircraft operation to the emission rate. Towing, fleet mix control, and engine emission standards substantially alter the distribution of CO and HC emissions among the modes. For towing, there is a marked reduction in taxi/idle emissions since aircraft are not operating engines in this mode. Fleet mix changes result in different aircraft operating procedures and hence different modal characteristics. Engine emission standards provide an across-the-board emission reduction

TABLE 15. Aircraft Emission Reductions Through Strategy Implementation[a]

	CO			HC			NO_x		
Strategy	Aircraft Emissions	% Change in Aircraft	% Change in Total Airport	Aircraft Emissions	% Change in Aircraft	% Change in Total Airport	Aircraft Emissions	% Change in Aircraft	% Change in Total Airport
Baseline	4,959			2,415			2,072		
Engine Shutdown	4,719	- 4.8	- 2.8	2,249	- 6.9	- 4.7	2,073	+ 0.0	+ 0.0
Towing	2,573	-48.1	-27.8	1,235	-48.9	-33.7	1,963	- 5.3	- 2.1
Capacity Control (65% LF)	4,737	- 4.4	- 3.5	2,305	- 4.6	- 3.4	1,979	- 4.5	- 3.7
Capacity Control (70% LF)	4,326	-12.8	- 9.5	2,128	-11.9	- 9.0	1,801	-13.1	-10.5
Fleet Mix	3,007	-39.4	-23.9	1,065	-55.9	-39.0	2,670	+28.9	+22.3
Engine Emission Standards	1,864	-62.4	-36.9	698	-71.1	-50.4	1,143	-44.8	-41.0

[a] All emissions in metric tons/yr.

TABLE 16. Aircraft and Ground Service Emissions by Operational Mode

Mode	Baseline	Engine Shutdown	Towing	Capacity Control (65% LF[b])	Capacity Control (70% LF[b])	Fleet Mix	Engine Emission Standards
% of CO Emissions							
Start up	13.5	14.0	21.1	13.5	13.5	24.2	5.6
Taxi out	23.7	24.7	3.2	23.7	23.5	23.5	14.0
Takeoff	1.4	1.4	2.2	1.4	1.4	0.4	1.9
Climb out	4.7	4.9	7.4	4.7	4.7	1.2	7.0
Approach	9.0	9.4	14.2	9.0	9.0	6.3	8.0
Landing	2.4	2.5	3.7	2.4	2.4	2.2	1.9
Taxi in	15.9	12.9	2.1	15.9	15.6	17.2	9.1
Shutdown	2.1	1.7	3.3	2.1	2.1	1.1	1.1
APU	2.6	2.7	4.1	2.6	2.7	3.3	5.0
Grnd Serv.	24.7	25.8	38.8	24.7	25.0	33.6	46.6
Total Emissions[a] (metric tons/yr)	6,585	6,329	4,200	6,289	5,771	4,529	3,491
% of HC Emissions							
Start up	22.3	23.9	40.4	22.3	22.3	10.7	7.1
Taxi out	27.2	29.1	1.4	27.2	27.1	21.7	12.2
Takeoff	0.2	0.2	0.3	0.2	0.2	0.2	0.1
Climb out	0.4	0.5	0.8	0.4	0.4	0.4	0.3
Approach	2.0	2.1	3.6	2.0	1.9	2.0	1.1
Landing	1.9	2.0	3.4	1.9	1.9	1.8	0.9
Taxi in	18.8	14.0	1.0	18.8	18.6	15.9	8.4
Shutdown	3.1	2.5	5.6	3.1	3.1	1.0	0.9
APU	0.3	0.2	0.5	0.3	0.3	0.5	0.8
Grnd Serv.	8.5	9.1	15.3	8.5	8.5	16.4	24.3
Fuel Refill.	15.4	16.4	27.8	15.4	15.5	29.4	44.1
Total Emissions[a] (metric tons/yr)	2,639	2,469	1,459	2,519	2,327	1,275	922
% of NO_x Emissions							
Start up	1.3	1.3	1.4	1.3	1.3	1.2	1.2
Taxi out	3.5	3.5	0.5	3.5	3.6	2.7	3.1
Takeoff	21.9	21.9	23.1	21.9	22.0	20.5	20.0
Climb out	32.2	32.2	34.0	32.2	32.3	30.7	34.0
Approach	25.2	25.1	26.5	25.1	24.8	30.1	20.2
Landing	7.1	7.1	7.5	7.1	7.2	8.3	8.2
Taxi in	2.3	2.5	0.3	2.3	2.4	2.0	2.0
Shutdown	0.2	0.2	0.2	0.2	0.2	0.1	0.2
APU	3.6	3.6	3.8	3.6	3.6	2.4	6.3
Grnd Serv.	2.7	2.6	2.7	2.7	2.7	1.9	4.7
Total Emissions[a] (metric tons/yr)	2,129	2,131	2,019	2,033	1,851	2,722	1,199

[a] Includes aircraft, APU, ground service vehicles.

[b] Load factor.

in all modes and elevate the ground service vehicle emissions to an overwhelming position. The relatively small change in engine shutdown modal distribution is a result of the limited application of the strategy as practiced at the Atlanta airport.

The implication of this review is that towing, fleet mix control, and engine emission standards will, in addition to lowering the overall CO and HC emission rate, alter the spatial emission pattern. The other control options will lower emissions but will maintain the same general distribution. This is significant to the determination of the air quality impacts in the immediate vicinity of the airport. None of the control options significantly alters the NO_x modal distribution. This is a result of the fact that these emissions occur primarily in the takeoff, climbout and approach modes. With the exception of the engine emission standards that provide an overall NO_x emission reduction, none of the strategies addresses itself to this problem.

Table 17 indicates the relative contribution of each aircraft class to the overall emissions. Aircraft, auxillary power unit (APU), and ground service equipment emissions have been included in the totals to demonstrate the added emission reductions resulting from ground service vehicle activity changes induced by aircraft activity changes. Comparison of this table to Table 5 yields some interesting observations. The DC-8 and CV-880 aircraft are contributing more to the total CO and HC emissions than their activity level would indicate. They account for about 12% of the activity but 33.9% of the CO and 62.4% of the HC under baseline conditions. Based on the observations at the Atlanta airport, one of the biggest problems with these aircraft is the exceptionally long time required to start the engines at the gate. Since these aircraft are not equipped with auxillary power units, they must remain in the gate position until all engines are running. The time from first engine start to the start of forward roll out of the ramp area was measured at an average of almost 7 minutes as compared with 1-2 minutes for all other aircraft, with the exception of the B-747. Only the application of engine emission standards alleviates the problem (at least within the limits of the assumption of uniform emission reductions among all operating modes). Fleet mix control removes these aircraft altogether but generates a similar problem with the jumbo jets which make up 24.4% of the new activity level but contribute 51.8% of the CO and 54.5% of the HC.

TABLE 17. Aircraft and Ground Service Vehicle Emissions by Aircraft Class

Aircraft Class[a]	Baseline	Engine Shutdown	Towing	Capacity Control (65% LF)	Capacity Control (70% LF)	Fleet Mix	Engine Emission Standards
	% of CO Emissions[a]						
Jumbo Jets (B-747, DC-10, L-1011)	4.4	4.7	4.3	4.4	4.2	51.8	5.3
Long-Range Jets (DC-8, CV-880)	33.9	32.9	30.4	33.9	34.3	0.0	15.7
Medium-Range Jets (DC-9, B-727)	44.2	44.3	45.7	44.2	44.7	40.4	53.5
Short-Range Aircraft (B-737, YS-11, M-404)	13.8	14.3	16.6	13.8	13.9	3.3	25.0
General Aviation (Jet, Piston)	3.7	3.8	3.0	3.7	2.9	4.5	0.5
	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	% of HC Emissions[a]						
Jumbo Jets	3.2	3.4	3.7	3.2	3.2	54.5	8.6
Long-Range Jets	62.4	61.1	53.7	62.4	62.7	0.0	23.3
Medium-Range Jets	30.9	31.9	38.8	30.9	31.0	40.0	61.2
Short-Range Aircraft	2.2	2.3	3.0	2.2	2.2	3.0	4.6
General Aviation	1.3	1.3	0.8	1.3	0.9	2.5	2.3
	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	% of NO_x Emissions[a]						
Jumbo Jets	8.7	8.7	9.0	8.7	7.3	61.6	6.5
Long-Range Jets	15.2	15.2	15.5	15.2	15.4	0.0	16.6
Medium-Range Jets	71.8	71.8	71.9	71.8	73.3	35.3	55.9
Short-Range Aircraft	3.4	3.4	2.8	3.4	3.5	2.4	3.5
General Aviation	0.9	0.9	0.8	0.9	0.5	0.7	17.5
	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[a] Includes aircraft, APU, ground service vehicles.

Figure 8 shows the impact of capacity control on emissions. The change is linear and the emissions decrease at a slightly higher rate (12.4% for CO, 11.8% for HC, and 13.1% for NO_x) than the activity decreases (10.8%). This is due to the aforementioned reduction in ground service vehicle emissions accompanying the aircraft activity decline.

Table 18 gives the normalized emission rates (aircraft and ground service vehicles) for the Atlanta airport for each control strategy. Since the number of enplaned passengers is constant in all strategies, the emissions-per-passenger reflect the same changes as were observed for the total emission reduction on Table 15. The number of LTO cycles, however, varies with the capacity control and fleet mix strategy. The results are that (1) capacity control produces virtually no change in the per-LTO emission rate and (2) the fleet mix control produces a smaller relative change in the per-LTO CO and HC emission rates than in the total emissions and a larger relative change in the per-LTO NO_x emission rate. This implies that fleet mix changes bring in aircraft with smaller CO and HC emission rates and that emissions are decreased further due to the reduced number of flights required to provide the same number of available seats. In contrast, the mix changes bring in aircraft with larger NO_x emission rates, but these are partially offset by the lower activity level.

There is a temptation to use the normalized emission rates on Table 18 to estimate emissions at other airports for the same strategies. This may be valid as a first approximation but should be treated with utmost care in attempting to select an appropriate control option for another airport. More detailed study of the local conditions may drastically change the relative merits of each strategy.

5.2 AIR QUALITY IMPACTS

5.2.1 Normal Conditions

In performing dispersion calculations with the short-term version of the AVAP model, it is necessary to specify distinct meteorological conditions. Choice of representative parameters for the strategy analysis was based on two criteria. First, the meteorological conditions chosen had to occur with sufficient frequency in the Atlanta area to be representative of

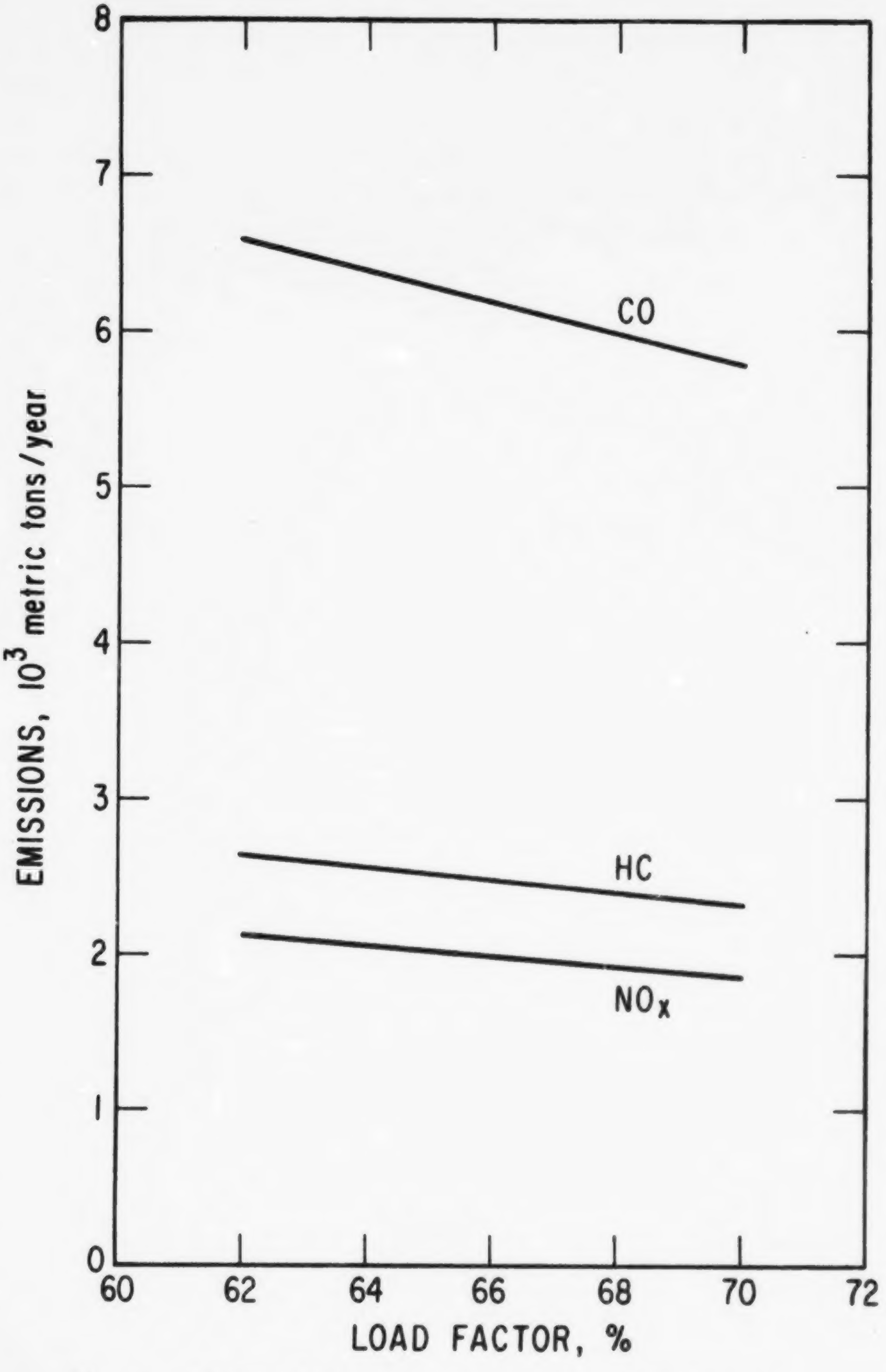


Fig. 8. Effect of Passenger Load Factor on Emissions

TABLE 18. Normalized Aircraft and Ground Service Vehicle Emission Rates

Emission Rate		Baseline	Engine Shutdown	Towing	Capacity Control (65% LF)	Capacity Control (70% LF)	Fleet Mix	Engine Emission Standards
kg/enplaned passenger	CO	.549	.527	.350	.524	.481	.377	.291
kg/enplaned passenger	HC	.220	.216	.122	.210	.194	.106	.077
kg/enplaned passenger	NO_x	.177	.178	.177	.169	.154	.227	.100
kg/LTO	CO	26.05	25.04	16.62	26.01	25.58	24.11	13.81
kg/LTO	HC	10.44	9.77	5.77	10.42	10.32	6.79	3.65
kg/LTO	NO_x	8.43	8.43	7.99	8.41	8.21	14.49	4.74

likely situations. Second, two very different air quality patterns can be expected when the wind blows from the north or from the south. Northerly winds carry the emissions from the city of Atlanta across the airport, while southerly winds carry little in the way of background emissions due to the relatively undeveloped area south of the airport (see map of Fig. 1). The chosen meteorological patterns should include at least one case representative of both wind directions.

Typical seasonal meteorological conditions for Atlanta were determined by looking at climatological records for the months of January, April, July, and October. The Decennial Census of United States Climate-Summary of Hourly Observations for 1951-60[15] was used to determine wind speed, wind direction, and temperature. Other data[16,17,18,19] were used to determine mixing depths and stability class. The conditions for July and October were chosen for the analysis since they best satisfied the two criteria. They are tabulated on Table 19 and are referred to as Summer and Fall respectively. (The wind directions for January and April were from 291° and 254°, respectively, and hence would not have provided a significantly different analysis than the July conditions.) Under the summer conditions, aircraft arrive and depart to the west and under fall conditions, to the east. The hour from 11:00-12:00 AM was used in the one-hour average calculations. It is the busiest air traffic hour of the day and its analysis represents maximum strategy impact.

TABLE 19. Typical Meteorological Conditions for Atlanta

	Summer (July)	Fall (October)
Wind Direction[a] (deg)	228	17
Wind Speed (m/sec)	3.5	4.0
Average Temperature (°F)	78.7	62.4
Stability Class[b]	4	4
Mid-Day		
Maximum Temperature (°F)	89	72
Mixing Depth (m)	1640	910
Night-Time		
Minimum Temperature (°F)	68	52
Mixing Depth (m)	100	100

[a] Northerly wind is 0°.

[b] Pasquill stability classification.

Figures 9a.-f., 10a.-f., and 11a.-f. show the calculated isopleths for CO, HC, and NO_x, respectively, for baseline conditions and each of the five strategies studied. The capacity control strategy is represented by the 70% load factor only. In addition to the graphical display, pollutant concentrations at various airport activity sites are tabulated on Tables 20, 21, and 22 for CO, HC, and NO_x, respectively. These sites were chosen as being representative of places where airport employees or passengers and visitors might be expected to spend significant amounts of time. Most of the activity sites are north of runway 8/26 (the northernmost), with the exception of the Delta Jet Base and the central fire station. The concentration at each site is obtained by averaging the concentrations calculated at several receptor locations in the vicinity of the site.

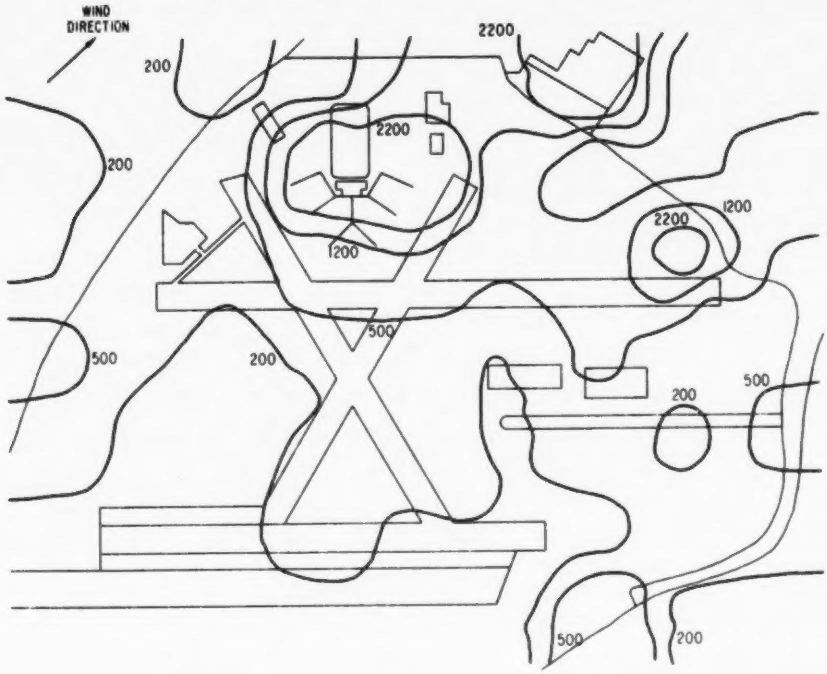
CO Analysis

The baseline CO isopleths of Fig. 9a. and Table 20 show the highest CO concentrations to be in the vicinity immediately downwind of the terminal for both summer and fall conditions. This is as expected since the terminal concentrates emissions from aircraft, ground service vehicles, and access traffic in one area. In addition, in summer there is a small "hot spot" at the northeast end of runway 8/26 and in fall it is at the southwest end. This is probably a result of takeoff queuing and the emissions associated with takeoff and climbout paths being blown back down to the ground. That similar peaks do not occur near the southern runways may be the result of a lower overall concentration at the site or the result of a lack of resolution in the model's receptor network.

Under summer conditions there is also a high concentration zone around the remote parking facilities northeast of the terminal, as a result of the terminal emissions being transported over the parking lot, which is an additional significant emission source. The combination creates a CO level comparable to that in the vicinity of the terminal itself.

The isopleths and Table 20 show that nowhere is the National Ambient Air Quality Standard for CO being exceeded. In fact, these values are well below the more stringent eight-hour standard of 10 mg/m^3. In this respect the model results are consistent with the GEOMET observations during the field test, which also indicated no violations.

ALL CONCENTRATIONS IN $\mu G/M^3$, 1-HOUR AVERAGE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SUMMER

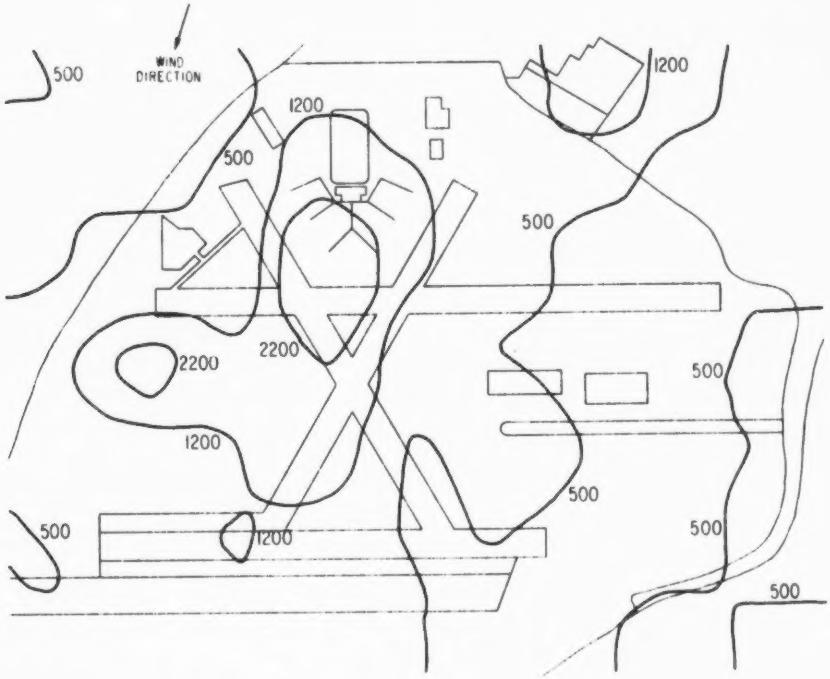
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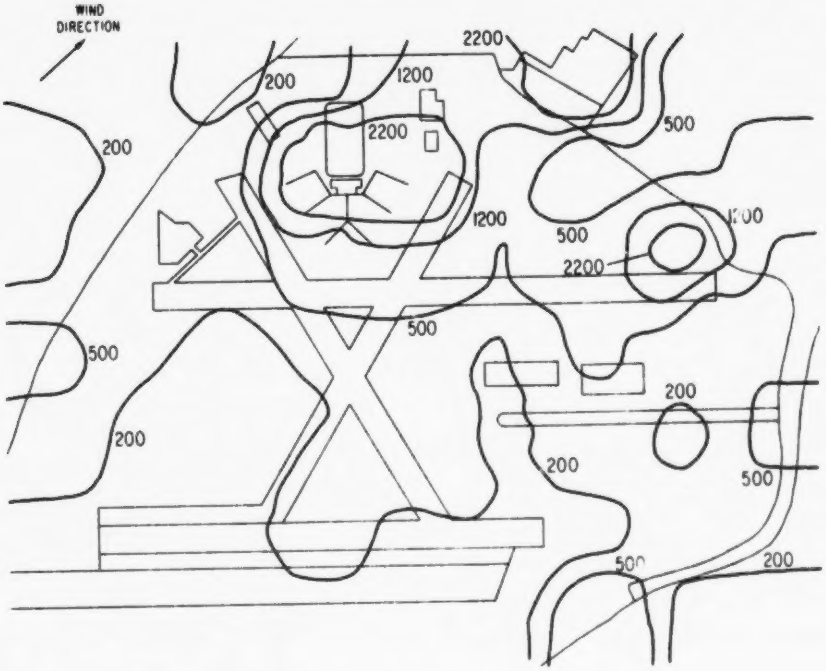
Fig. 9a. Airport CO Concentrations for Baseline Conditions

ALL CONCENTRATIONS IN $\mu G/M^3$, 1-HOUR AVERAGE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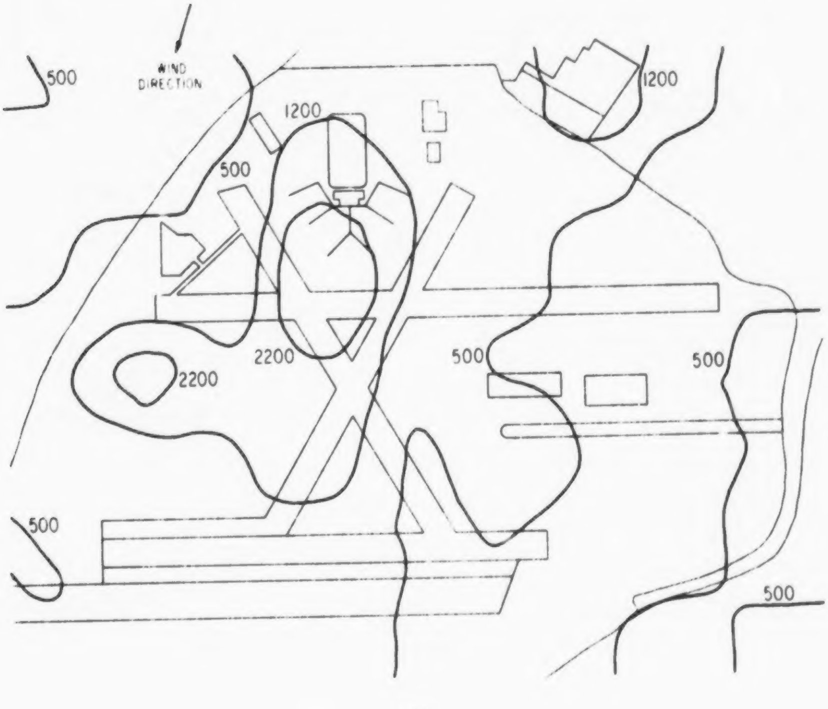
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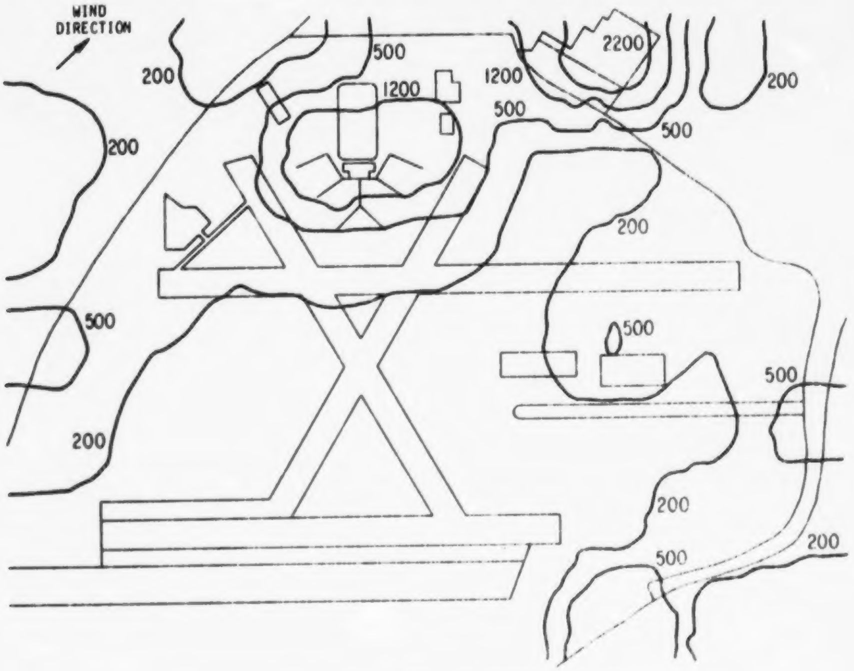
Fig. 9b. Airport CO Concentrations for Engine Shutdown Strategy

ALL CONCENTRATIONS IN μG/M³, 1-HOUR AVERAGE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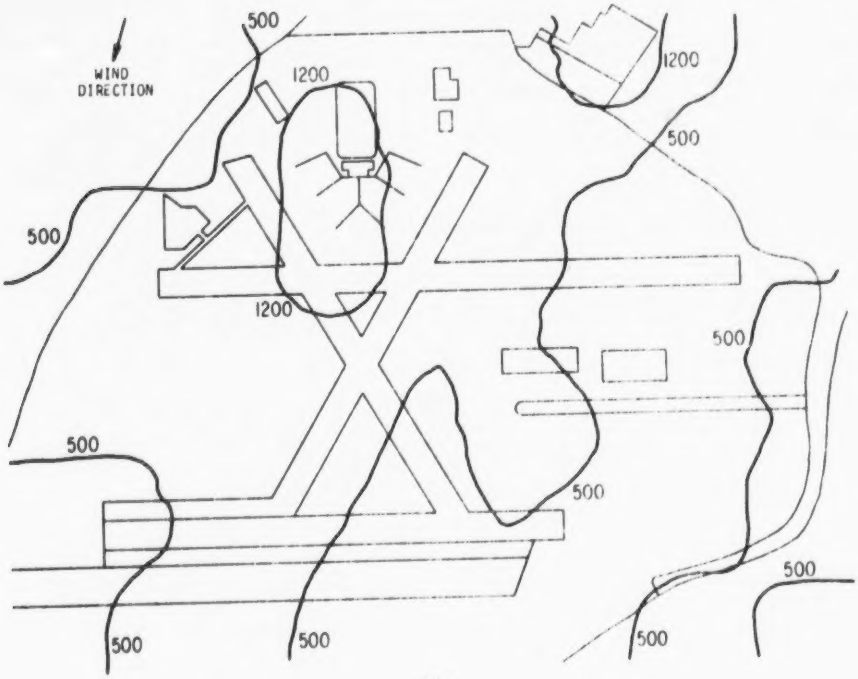
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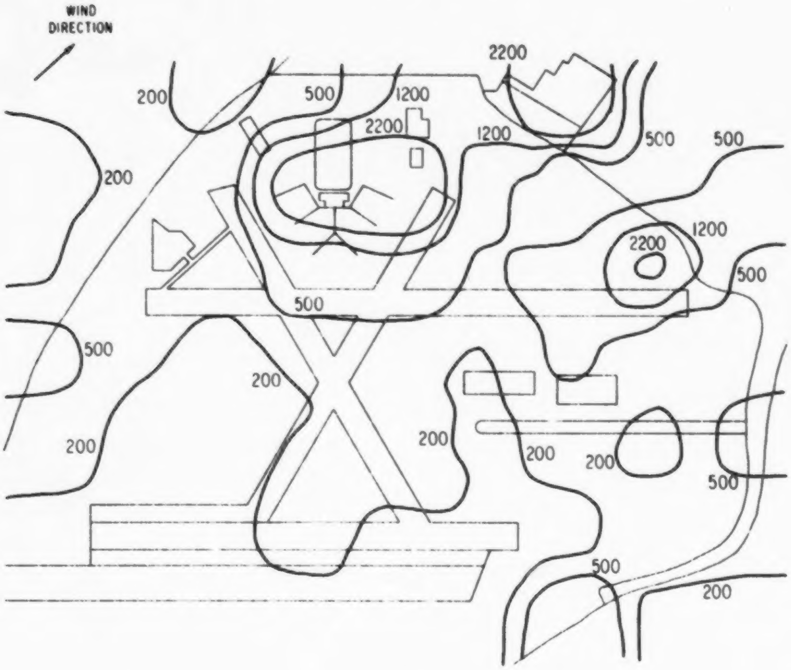
FALL

Fig. 9c. Airport CO Concentrations for Towing Strategy

ALL CONCENTRATIONS IN μG/M³, 1-HOUR AVERAGE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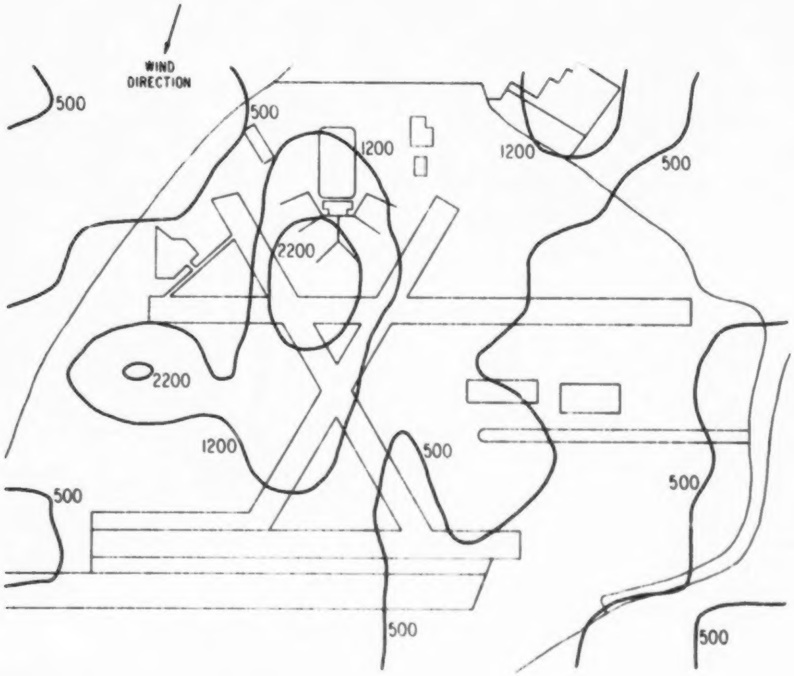
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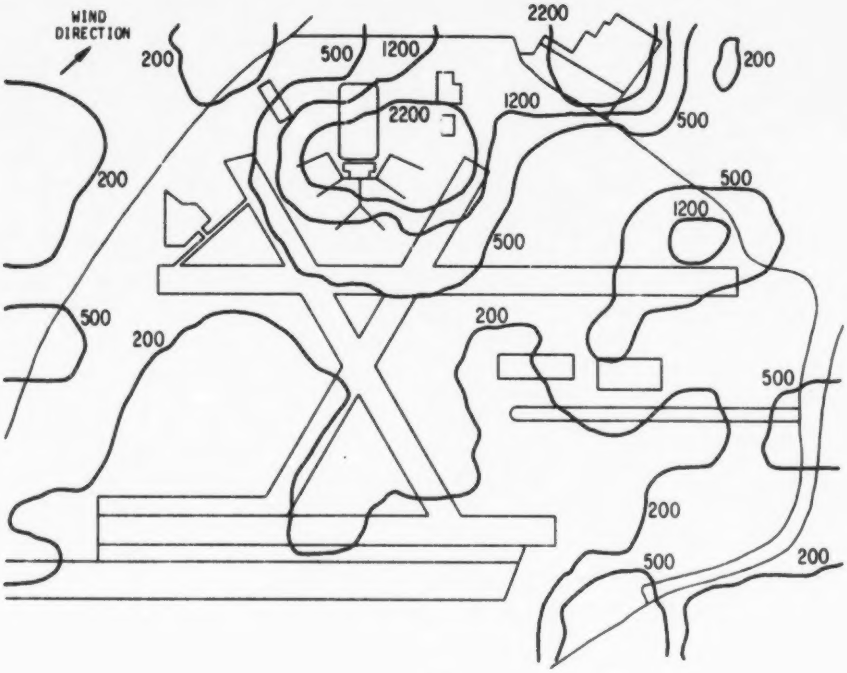
Fig. 9d. Airport CO Concentrations for Capacity Control Strategy

ALL CONCENTRATIONS IN μG/M³, 1-HOUR AVERAGE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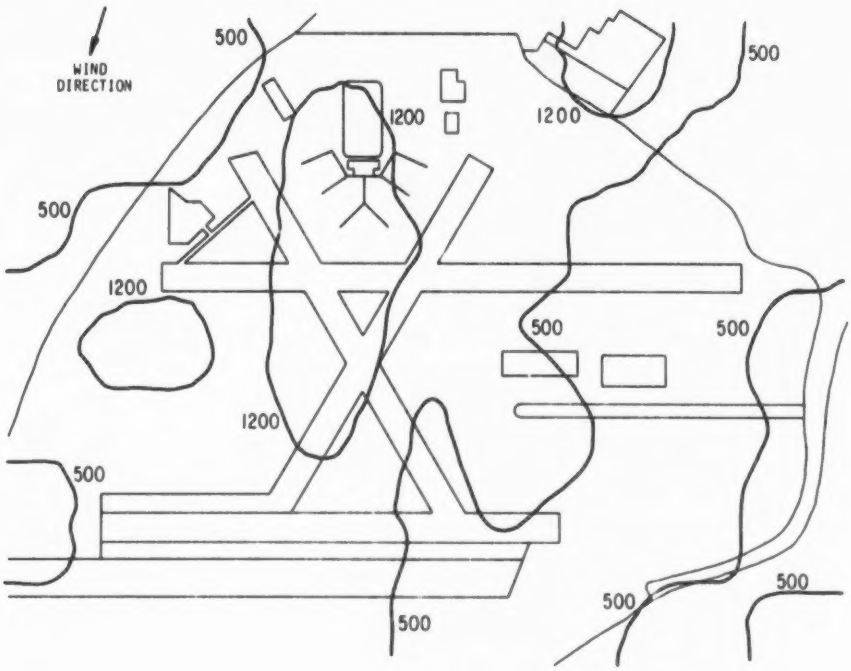
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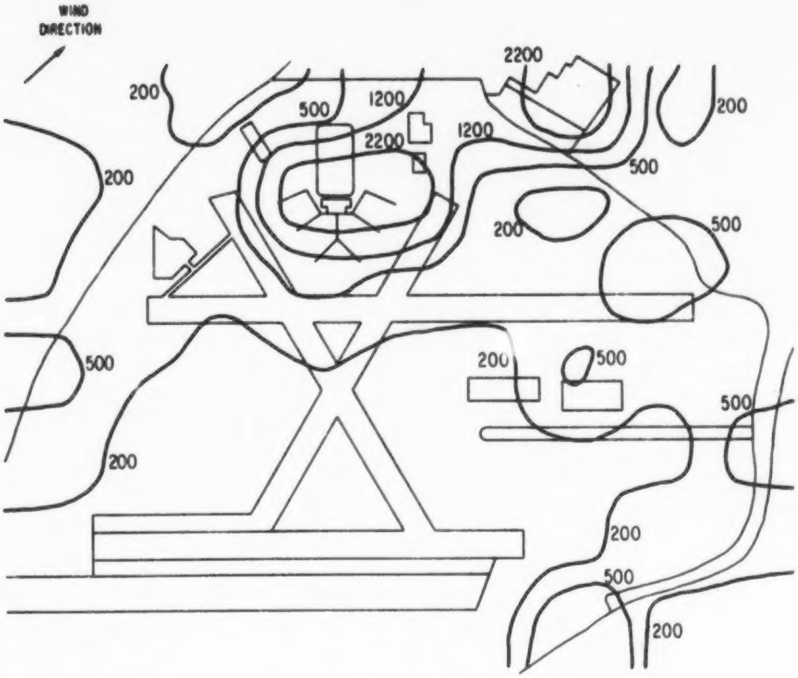
Fig. 9e. Airport CO Concentrations for Fleet Mix Strategy

ALL CONCENTRATIONS IN μG/M³, 1-HOUR AVERAGE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SUMMER

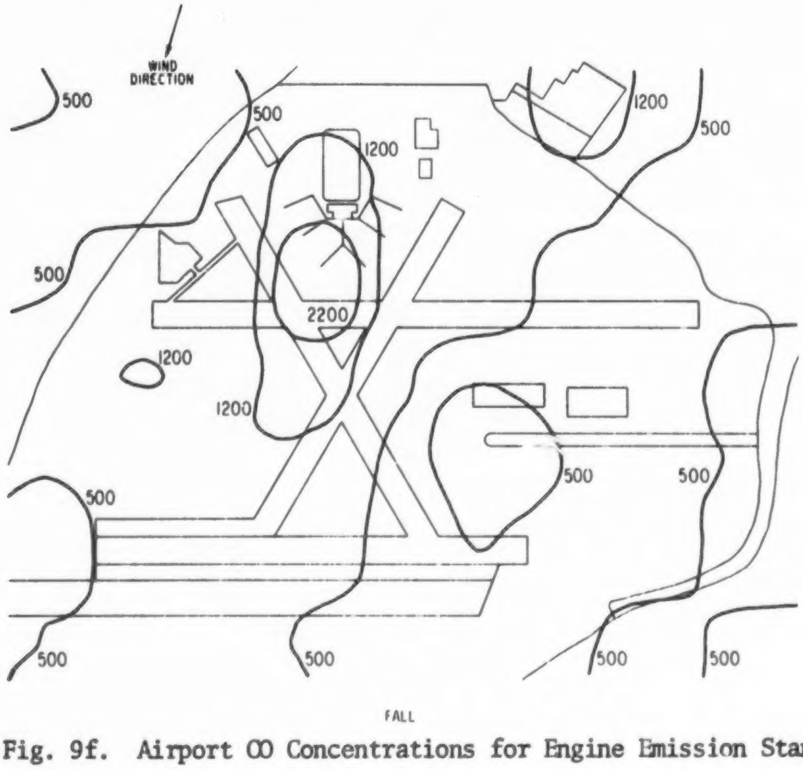
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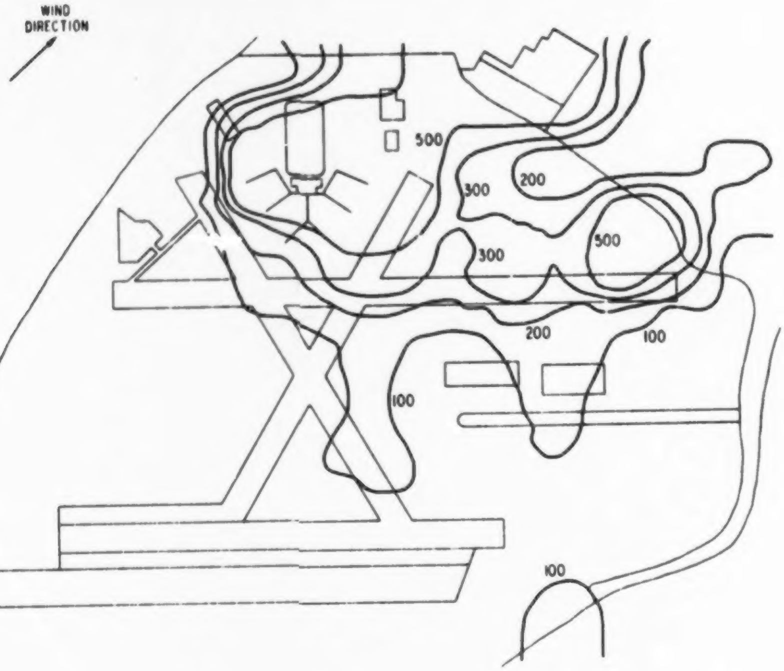
Fig. 9f. Airport CO Concentrations for Engine Emission Standards

ALL CONCENTRATIONS IN $\mu G/M^3$, 1-HOUR AVERAGE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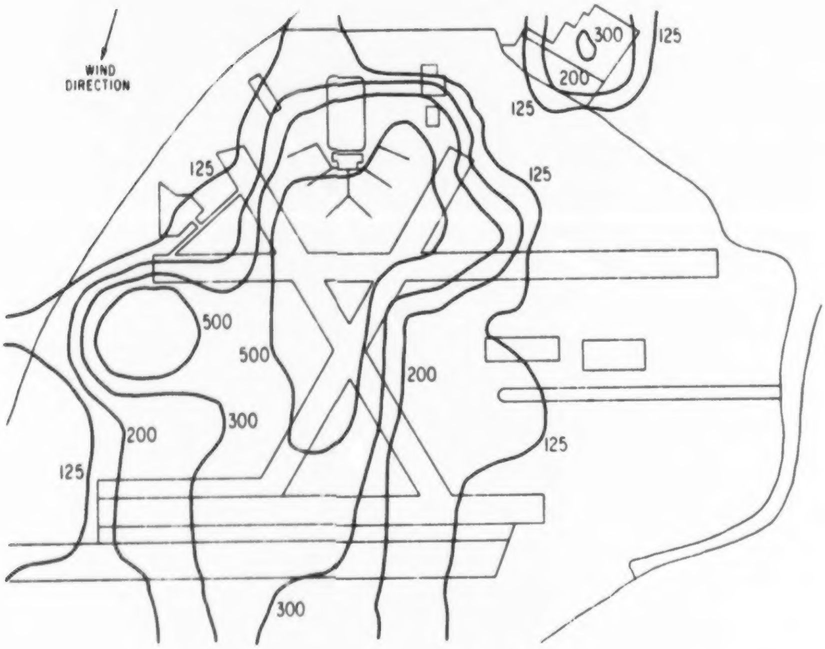
SUMMER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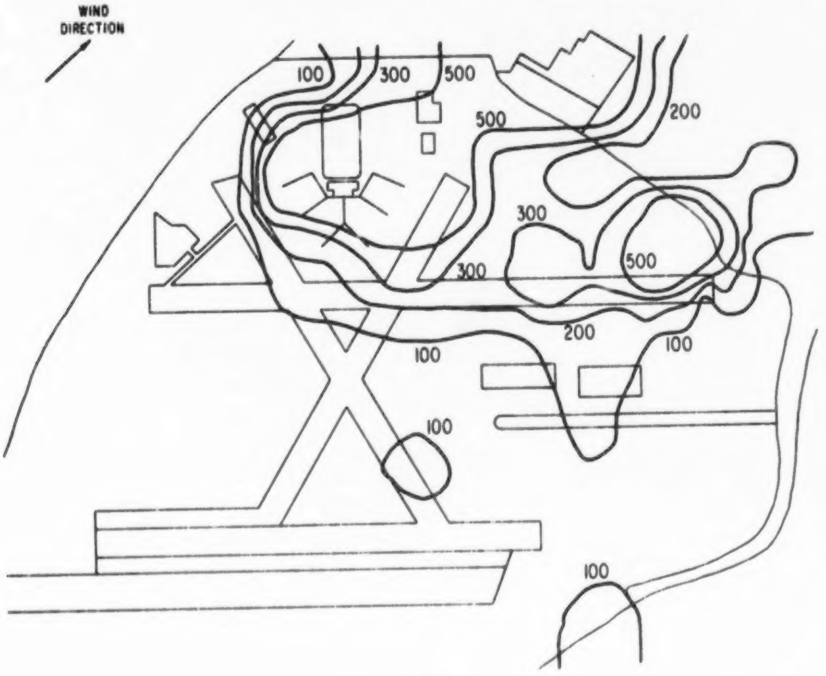
300

FALL

Fig. 10a. Airport HC Concentrations for Baseline Conditions

ALL CONCENTRATIONS IN μG/M³, 1-HOUR AVERAGE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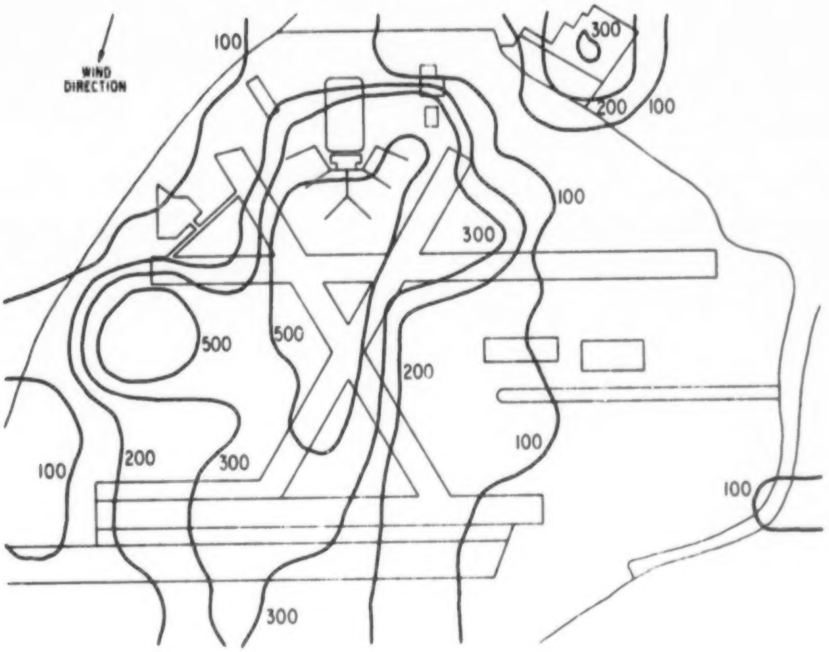
SUMMER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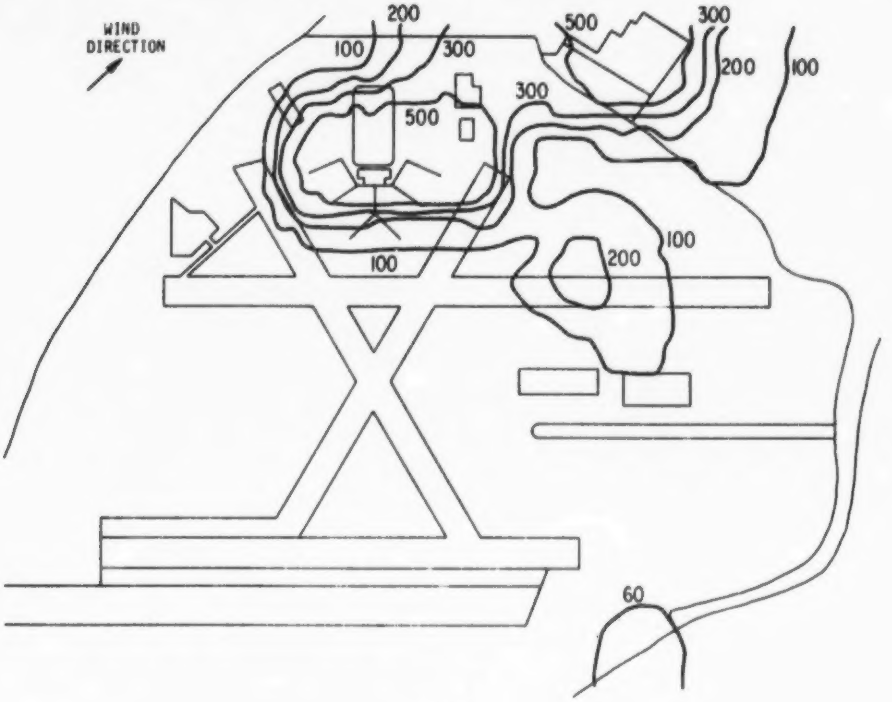
FALL

Fig. 10b. Airport HC Concentrations for Engine Shutdown Strategy

ALL CONCENTRATIONS IN μG/M^3, 1-HOUR AVERAGE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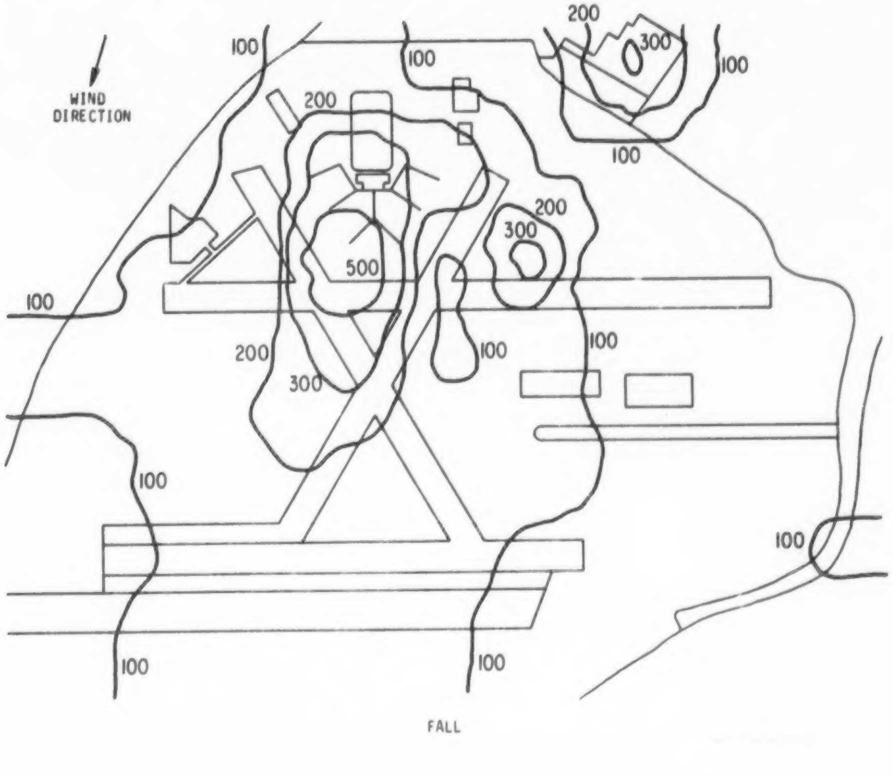
SUMMER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WIND DIRECTION
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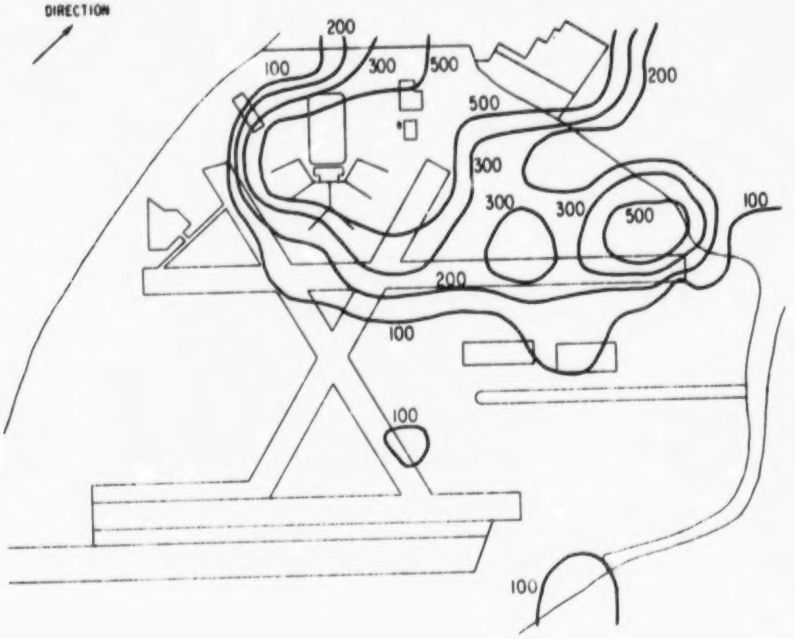
100
100
100
100
100

FALL

ALL CONCENTRATIONS IN µG/M³, 1-HOUR AVERAGE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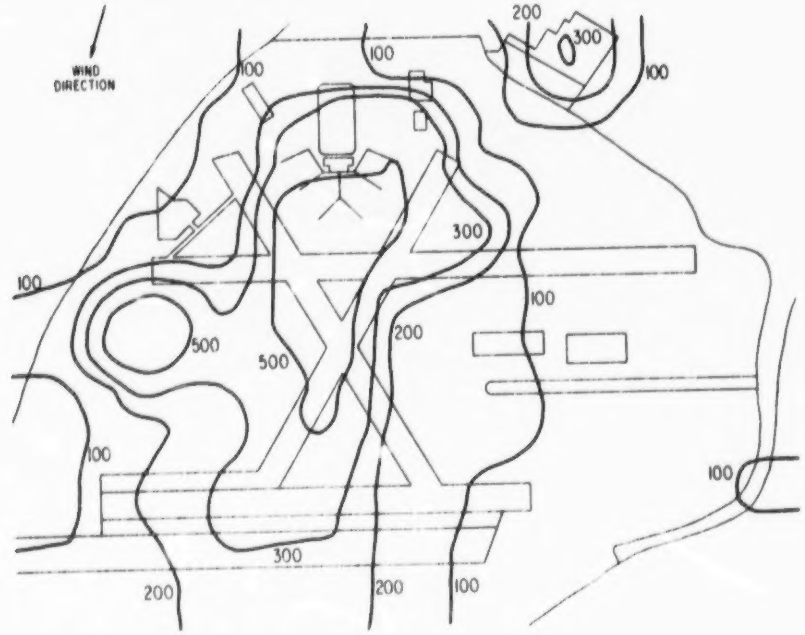
SUMMER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500
500
200
100
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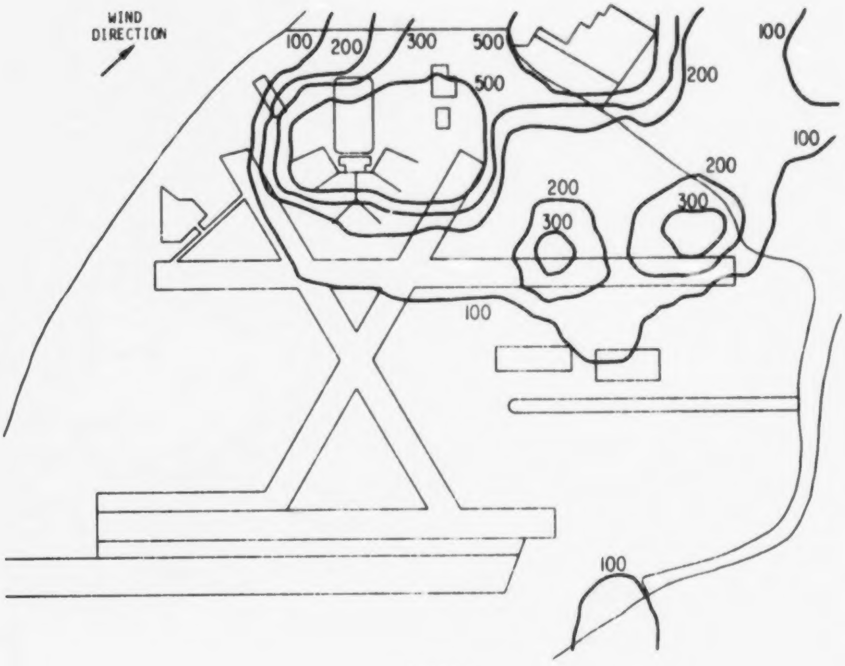
300
200
200
100

FALL

Fig. 10d. Airport HC Concentrations for Capacity Control Strategy

ALL CONCENTRATIONS IN $\mu G/M^3$, 1-HOUR AVERAGE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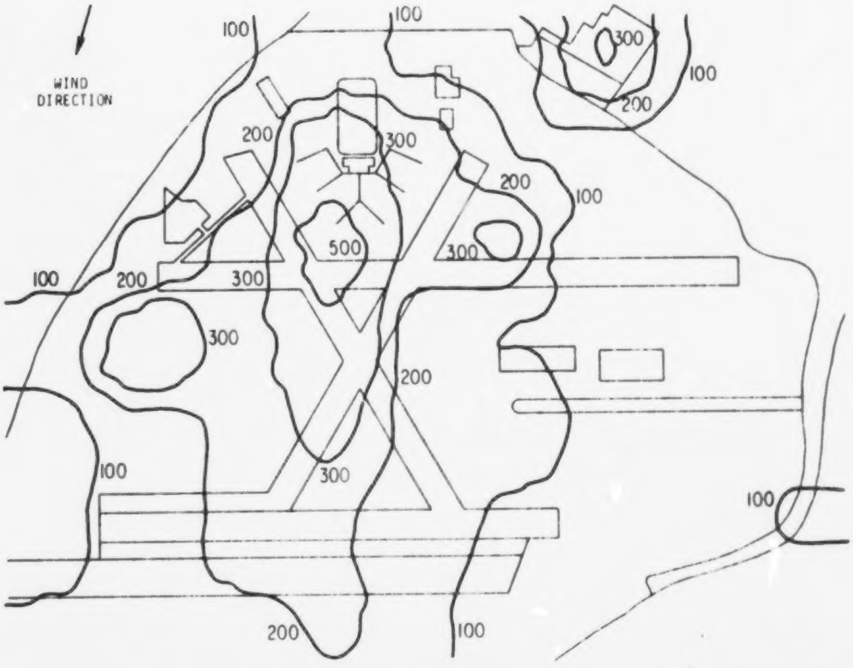
SUMMER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300
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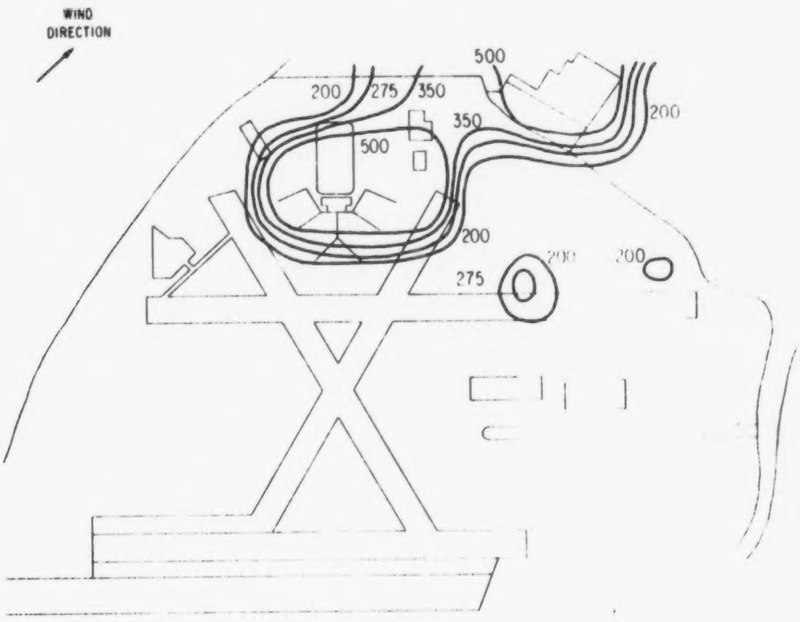
300
100
200
100

FALL

Fig. 10e. Airport HC Concentrations for Fleet Mix Strategy

ALL CONCENTRATIONS IN $\mu G/M^3$, 1-HOUR AVERAGE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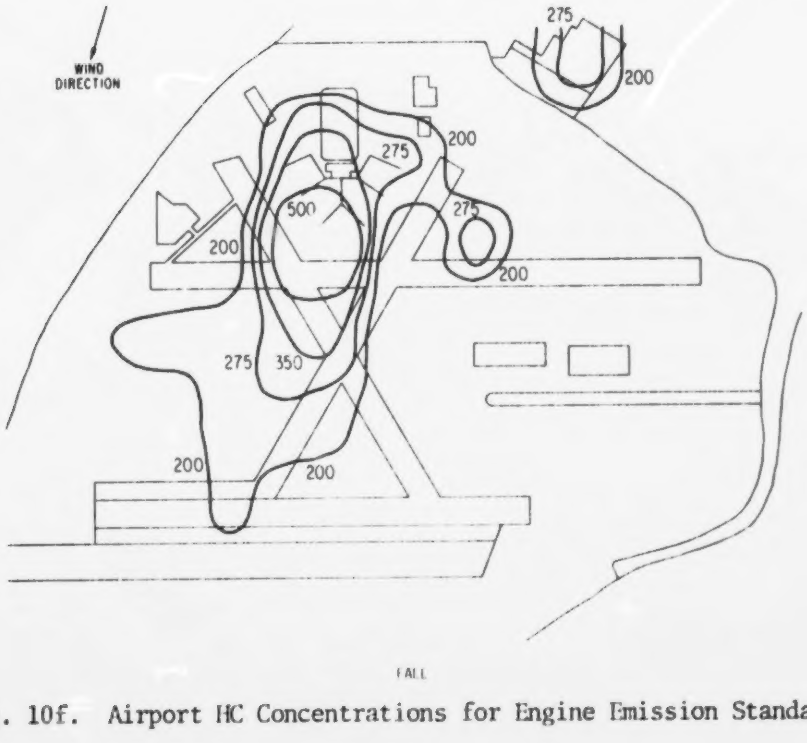
275

SUMMER


WIND DIRECTION
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200
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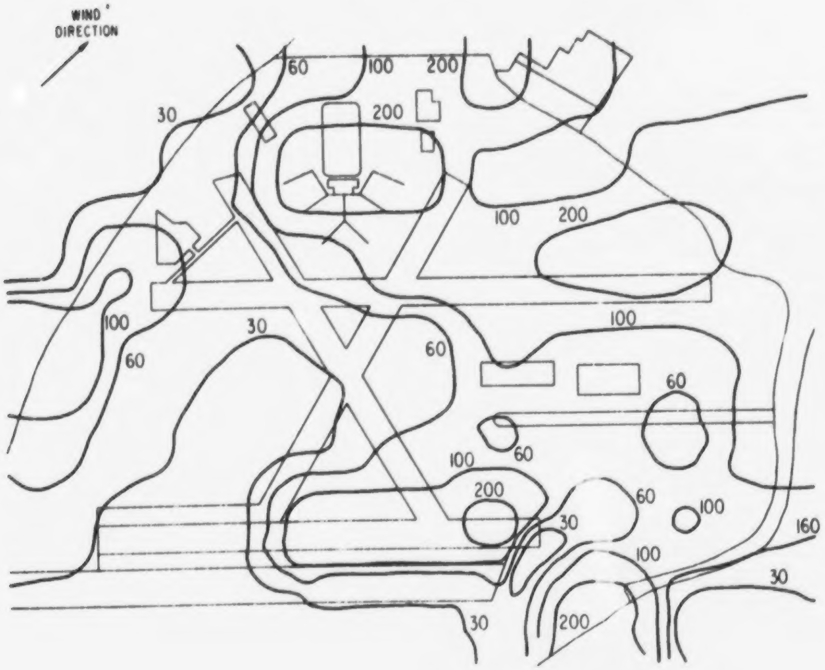
FALL

Fig. 10f. Airport HC Concentrations for Engine Emission Standards

ALL CONCENTRATIONS IN $\mu G/M^3$, 1-HOUR AVERAGE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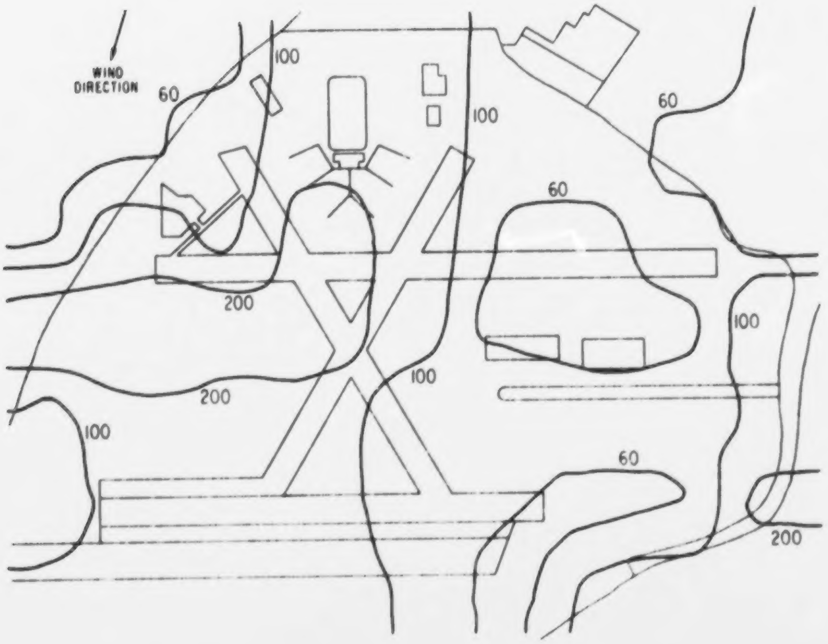
30
200

SUMMER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WIND DIRECTION
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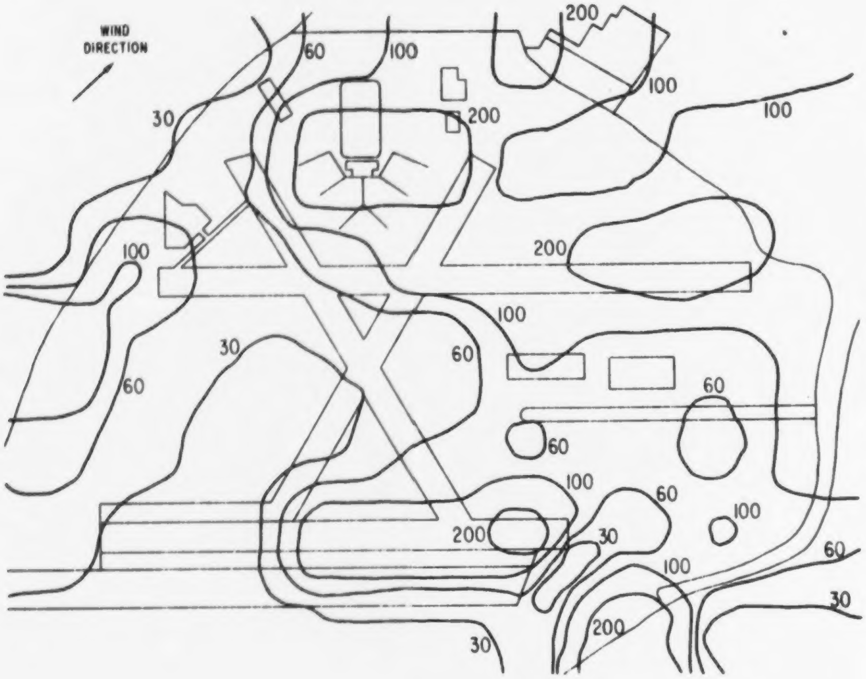
60
200

FALL

Fig. 11a. Airport NO_x Concentrations for Baseline Conditions

ALL CONCENTRATIONS IN μG/M³, 1-HOUR AVERAGE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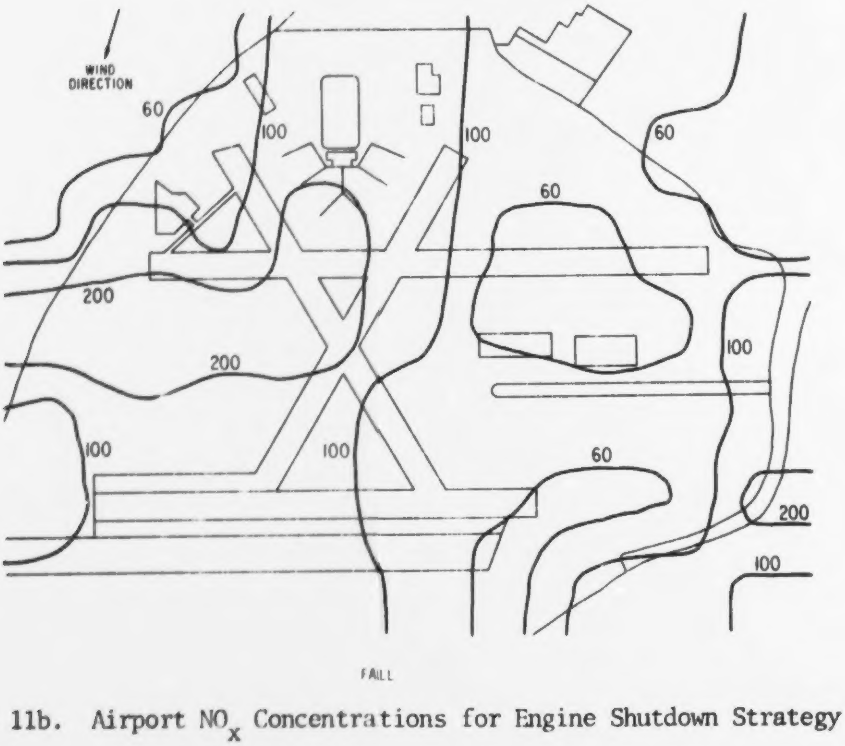
SUMMER


WIND DIRECTION
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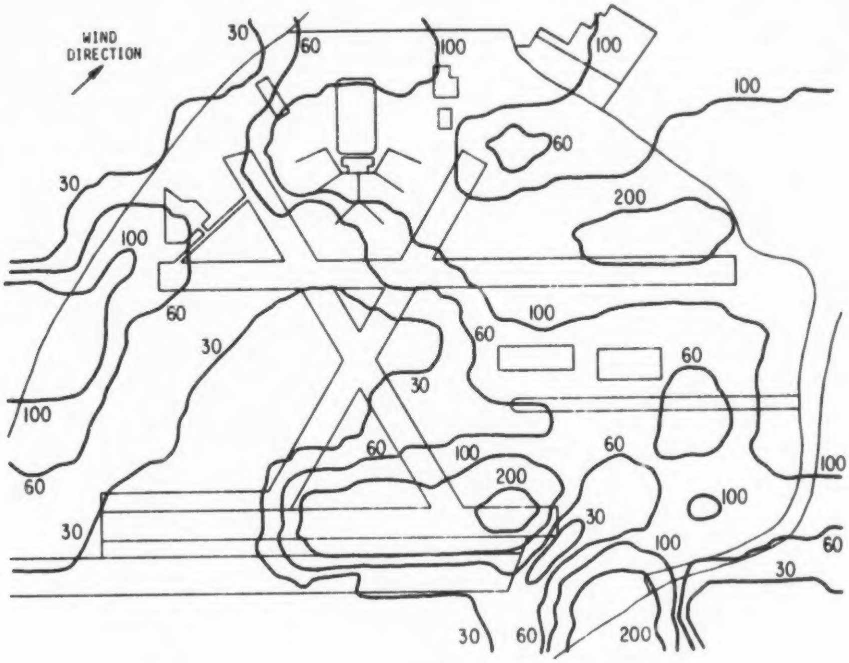
FALL

Fig. 11b. Airport NO_x Concentrations for Engine Shutdown Strategy

ALL CONCENTRATIONS IN $\mu G/M^3$, 1-HOUR AVERAGE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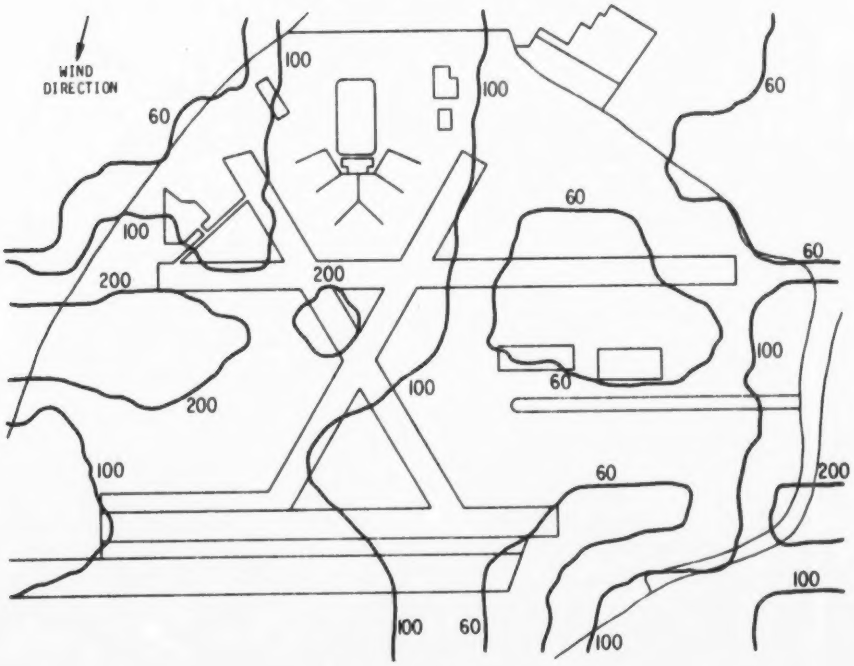
SUMMER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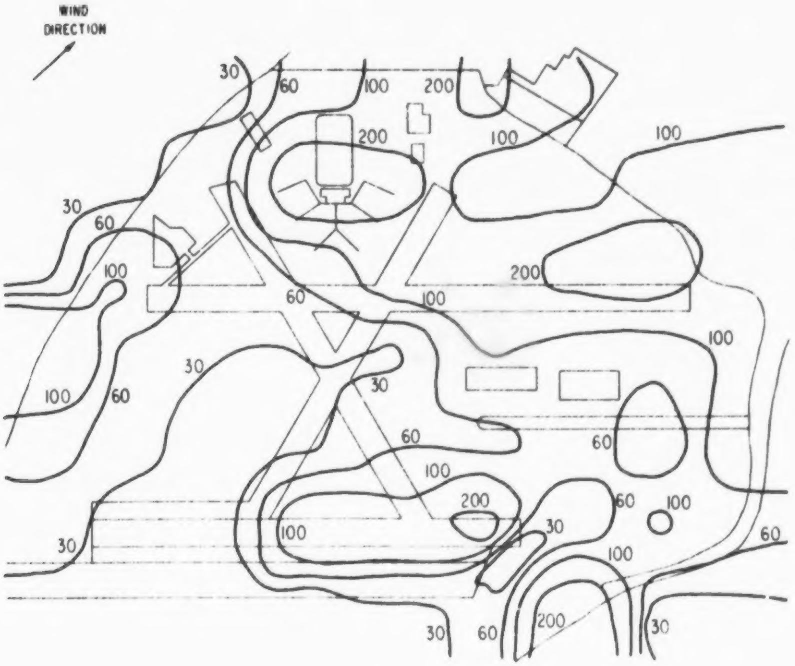
FALL

Fig. 11c. Airport NO_x Concentrations for Towing Strategy

ALL CONCENTRATIONS IN $\mu G/M^3$, 1-HOUR AVERAGE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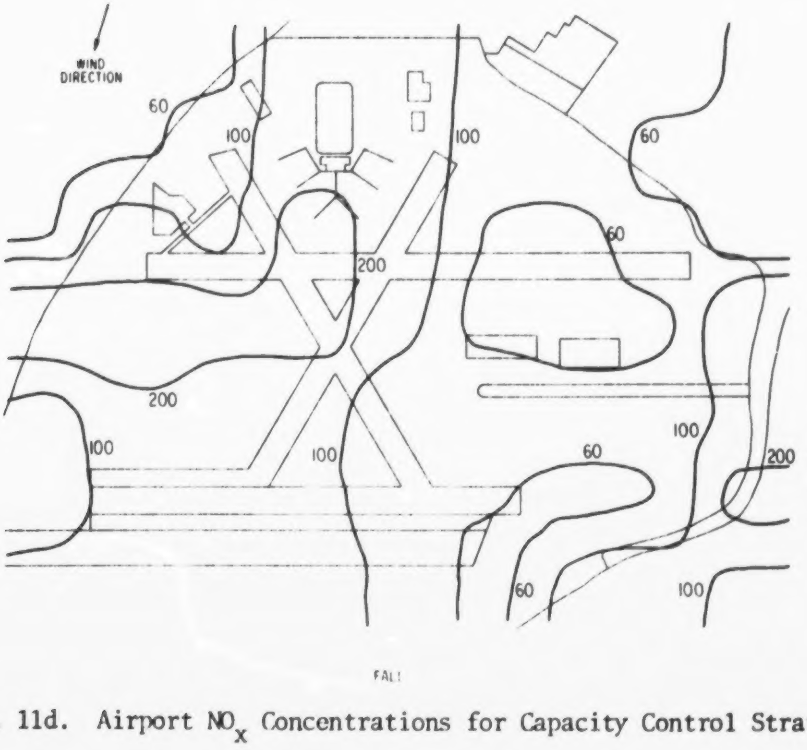
SUMMER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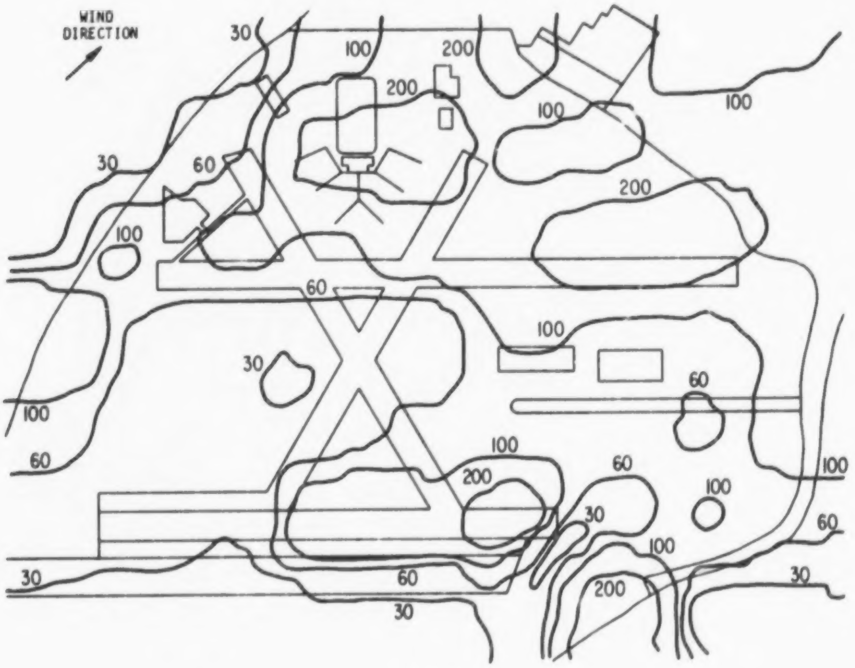
FALL

Fig. 11d. Airport NO_x Concentrations for Capacity Control Strategy

ALL CONCENTRATIONS IN μG/M³, 1-HOUR AVERAGE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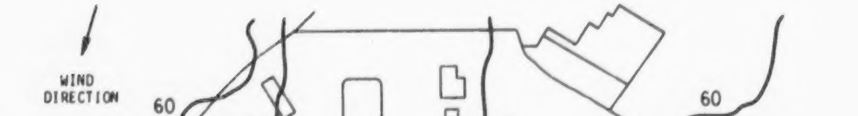
SUMMER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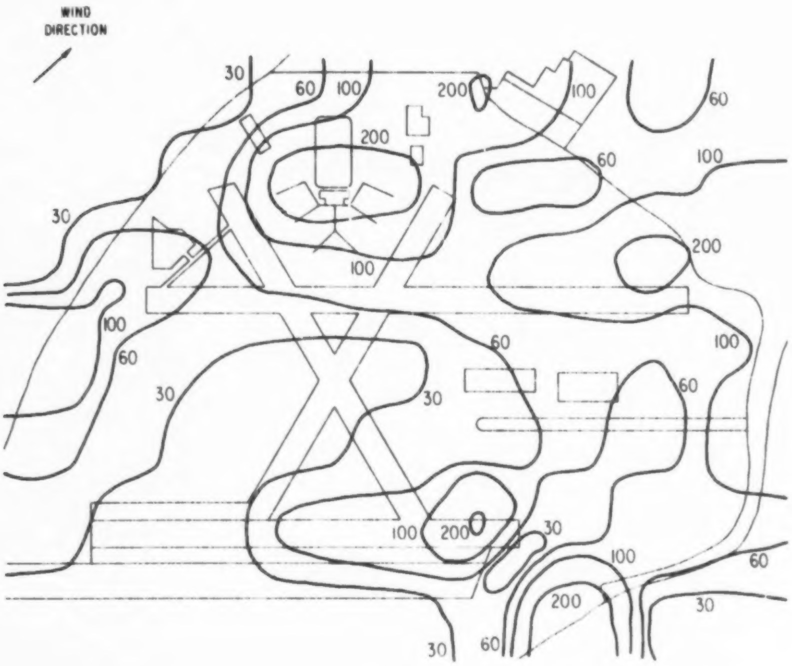
FALL

Fig. 11e. Airport NO_x Concentrations for Fleet Mix Strategy

ALL CONCENTRATIONS IN $\mu G/M^3$, 1-HOUR AVERAGE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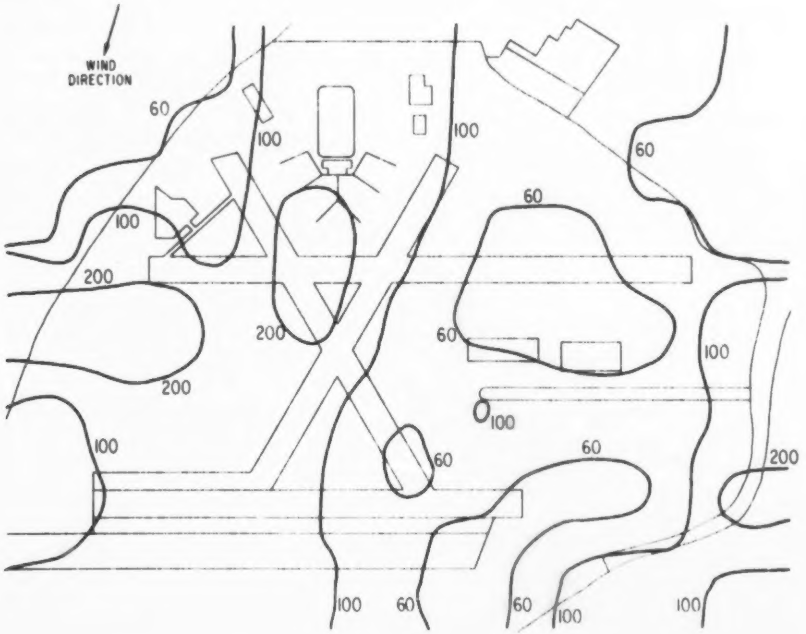
SUMMER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60
100
100

FALL

Fig. 11f. Airport NO_x Concentrations for Engine Emission Standards

TABLE 20. Airport CO Concentrations for Normal Conditions[a]

Location	Baseline	Engine Shutdown	% Change	Towing	% Change	Capacity Control (70% LF)	% Change	Fleet Mix	% Change	Emission Standards	% Change
Terminal: Parking Lot											
Summer	1859.0	1831.0	-1.5	1148.3	-38.2	1727.3	-7.1	1516.4	-18.4	1623.2	-12.7
Fall	1529.0	1529.0	0.0	1527.5	-0.1	1529.0	0.0	1532.0	+0.2	1529.0	0.0
Terminal: Aircraft Ramp											
Summer	2846.0	2770.0	-2.7	948.5	-66.7	2537.0	-10.9	2400.9	-15.6	1755.7	-38.3
Fall	2492.0	2472.0	-0.8	1430.7	-42.6	2289.5	-8.1	1453.0	-41.7	2213.7	-11.2
Delta Jet Base											
Summer	315.0	312.9	-0.8	214.9	-31.8	287.7	-8.8	255.5	-18.9	231.2	-26.6
Fall	537.0	532.7	-0.8	540.7	+0.7	535.4	-0.3	538.2	-0.2	523.5	-2.6
Eastern Hangar											
Summer	309.3	309.3	0.0	295.5	-4.5	308.8	-0.2	307.7	-0.5	295.2	-4.6
Fall	550.3	550.1	0.0	542.2	-1.5	548.6	-0.3	561.9	+2.1	548.8	-0.3
General Aviation Hangar											
Summer	385.0	384.9	-0.0	384.9	-0.0	384.9	-0.0	384.9	-0.0	384.9	0.0
Fall	699.4	699.4	0.0	694.5	-0.7	699.2	-0.0	698.8	-0.1	694.4	-0.7
Cargo Area											
Summer	977.8	946.9	-3.2	607.8	-37.8	920.2	-5.9	861.6	-11.9	737.2	-24.6
Fall	661.2	661.2	0.0	661.2	0.0	661.2	0.0	661.2	0.0	661.3	0.0
Central Fire Station											
Summer	378.2	368.4	-2.6	123.3	-67.4	334.3	-11.6	276.7	-26.8	188.2	-50.3
Fall	456.6	447.5	-2.0	421.2	-7.8	449.2	-1.6	439.0	-3.9	419.8	-8.1
Worst Receptor											
Summer (#153)	4854.0	4726.0	-2.6	1560.0	-67.9	4315.0	-11.1	4195.0	-13.6	2943.0	-39.4
Fall (#145)	3762.0	3755.0	-0.2	2142.0	-43.1	3434.0	-8.7	2138.0	-43.2	3540.0	-5.9

[a] All concentrations in $\mu g/m^3$, 1-hr average.

TABLE 21. Airport HC Concentrations for Normal Conditions[a]

Location	Baseline	Engine Shutdown	% Change	Towing	% Change	Capacity Control (70% LF)	% Change	Fleet Mix	% Change	Emission Standards	% Change
Terminal: Parking Lot											
Summer	595.2	587.1	-1.4	468.6	-21.3	537.7	-9.7	446.2	-25.0	536.0	-9.9
Fall	267.2	267.2	0.0	267.0	-0.1	261.7	0.0	268.3	+0.4	267.2	0.0
Terminal: Aircraft Ramp											
Summer	1467.0	1414.0	-3.6	592.5	-59.6	1301.6	-11.3	849.3	-42.1	677.1	-53.8
Fall	717.8	703.4	-2.0	463.0	-35.5	653.2	-9.0	397.2	-44.7	550.1	-23.4
Delta Jet Base											
Summer	85.4	84.5	-1.0	45.6	-46.6	75.8	-11.2	58.6	-31.4	45.0	-47.3
Fall	96.2	91.7	-4.7	98.7	-2.6	94.6	-1.6	87.3	-9.3	83.5	-13.2
Eastern Hangar											
Summer	49.4	49.4	0.0	47.2	-4.5	49.2	-0.3	49.0	-0.8	49.0	-0.8
Fall	117.0	117.0	0.0	115.7	-1.1	116.3	-0.6	122.3	+4.5	116.6	-0.3
General Aviation Hangar											
Summer	50.5	50.5	0.0	50.5	0.0	50.5	0.0	50.5	0.0	50.5	0.0
Fall	104.6	104.6	0.0	103.9	-0.7	104.6	0.0	104.5	0.0	104.5	0.0
Cargo Area											
Summer	334.6	314.6	-6.0	191.3	-42.8	307.5	-8.1	236.3	-29.4	208.2	-37.8
Fall	91.4	91.4	0.0	91.4	0.0	91.4	0.0	91.4	0.0	91.4	0.0
Central Fire Station											
Summer	117.1	114.2	-2.5	18.4	-84.5	102.9	-12.1	60.8	-48.1	30.6	-73.9
Fall	164.0	158.4	-3.4	145.5	-11.3	161.1	-1.8	150.6	-8.2	144.6	-11.9
Worst Receptor											
Summer (#153)	2739.0	2640.0	-3.6	1109.0	-59.5	2428.0	-11.4	1554.0	-43.3	1241.0	-54.7
Fall (#145)	897.2	894.3	-0.3	660.1	-26.4	809.9	-9.7	558.1	-37.8	811.0	-9.6

[a] All concentrations in $\mu g/m^3$, 1-hr average.

TABLE 22. Airport NO_x Concentrations for Normal Conditions[a]

Location	Baseline	Engine Shutdown	% Change	Towing	% Change	Capacity Control (70% LF)	% Change	Fleet Mix	% Change	Emission Standards	% Change
Terminal: Parking Lot											
Summer	191.3	191.0	-0.2	132.0	-31.0	180.2	-5.8	168.4	-12.0	169.1	-11.6
Fall	167.1	167.1	0.0	167.0	-0.1	167.1	0.0	167.2	+0.1	167.1	0.0
Terminal: Aircraft Ramp											
Summer	164.7	164.4	-0.2	76.9	-53.3	149.0	-9.6	201.9	+22.6	149.4	-9.3
Fall	215.4	215.2	-0.1	158.7	-26.3	203.9	-5.4	175.7	-18.4	208.2	-3.4
Delta Jet Base											
Summer	81.5	81.6	+0.0	76.3	-6.4	76.1	-6.6	86.4	+6.0	58.8	-27.9
Fall	67.3	67.3	0.0	67.4	+0.1	67.2	-0.1	68.2	+1.3	67.1	-0.3
Eastern Hangar											
Summer	57.6	57.6	0.0	57.5	-0.2	57.6	0.0	57.6	0.0	58.7	+1.8
Fall	83.6	83.6	0.0	82.9	-0.8	83.4	-0.2	84.0	+0.5	83.4	-0.2
General Aviation Hangar											
Summer	94.2	94.2	0.0	94.2	0.0	94.2	0.0	94.2	0.0	94.2	0.0
Fall	131.5	131.5	0.0	131.5	0.0	131.5	0.0	131.5	0.0	131.8	0.2
Cargo Area											
Summer	96.2	96.3	+0.1	74.0	-23.1	90.9	-5.5	100.1	+4.1	84.1	-12.6
Fall	108.1	108.1	0.0	108.1	0.0	108.1	0.0	108.1	0.0	108.1	0.0
Central Fire Station											
Summer	70.4	70.5	+0.1	56.8	-19.3	63.7	-9.5	75.3	+7.0	42.0	-40.3
Fall	66.3	66.3	0.0	64.7	-2.4	65.2	-1.6	68.3	+3.0	59.9	-9.6
Worst Receptor											
Summer (#162)	361.5	361.5	0.0	361.5	0.0	361.5	0.0	361.5	0.0	361.5	0.0
Fall (#130)	452.7	452.7	0.0	366.2	-19.1	408.8	-9.7	501.2	+10.7	336.8	-25.6

[a] All concentrations in $\mu g/m^3$, 1-hr average.

Comparison of the isopleths for engine shutdown (Fig. 9b.), and capacity control (Fig. 9d.) to the baseline conditions show virtually no change. Likewise, Table 20 shows only small changes at the activity sites, with the central fire station showing a maximum of an 11.6% decrease as the result of the capacity control option. The towing, fleet mix, and engine emission standards (Figs. 9c., e., f., respectively) showed marked alteration in the air quality patterns. All reduce the area contained within the high concentration isopleths as well as lower the overall concentration levels. Under fall conditions, and to a lesser extent under summer conditions, there is a persistent set of isopleths at the 500 $\mu g/m^3$ level that appears particularly insensitive to the control strategy applied. These levels are being generated primarily by the road traffic on the highways surrounding the airport.

It is significant to note the difference between the aircraft CO emission reductions given on Table 15 and the actually realized air quality improvements given on Table 20. The engine shutdown, capacity control, and engine emission standards options show maximum air quality improvements that are somewhat less than the aircraft emission reductions. Towing and fleet mix controls show air quality improvements that are greater than the aircraft emission reductions. The reasons for this have been alluded to previously. Towing drastically changes the spatial emission pattern as well as reduces overall emissions. By removing the engine startup and taxi/idle emissions from the terminal area, this strategy prevents a concentration of emission sources. Fleet mix controls provide the added benefit of reduced ground service vehicle requirements, hence achieving a somewhat higher level of air quality improvement. The other three strategies do not change the emission pattern enough to gain any additional air quality benefits other than the overall emission reduction.

The engine shutdown strategy as practiced during the field test is especially disappointing and provides only a little more than 3% improvement in air quality. Given this small difference it is not surprising that the CO field observations were not able to detect any statistically significant change.

HC Analysis

The HC isopleths of Figs. 10a.-f. and Table 21 show basically the same behavior as the CO data. Highest concentrations are immediately downwind of the terminal. There is a "hot spot" northeast of runway 8/26 in the summer and southwest of it in fall corresponding to queuing and takeoff emissions. There is another hot spot corresponding to emissions from the fuel farms just north of 8/26 and east of the terminal. This is readily apparent in Figs. 10.e. and f. As with CO, high HC concentrations are calculated in the remote parking facility during summer conditions.

It is evident from looking at the figures that a potential exists for violation of the National Ambient Air Quality Standard for hydrocarbons. The calculated concentrations are far in excess of the allowable concentration of 160 $\mu g/m^3$. At this point it is not possible to say that the standard is being violated for two reasons. First, the standard is based on a three-hour average as opposed to the one-hour average used here. The persistence of the given emission pattern and meteorological conditions for three consecutive hours would, in fact, indicate a violation. Second, the standard is based on the concentration measured for the hours 6-9 AM while these calculations were performed for 11-12 AM. (It will be shown later that the three-hour average concentration calculated for 6-9 AM does, in fact, exceed the standard of 160 $\mu g/m^3$.) Despite these two reservations, it is significant to note that none of the control strategies is completely successful in reducing the concentrations below the standards. Table 21 shows that the towing, fleet mix, and engine emission standards are the most effective strategies in reducing concentrations at the airport activity sites, although four of the sites are still in excess of the 160 $\mu g/m^3$ standard for all of the options. Note also from Table 14 that aircraft are responsible for about 2/3 of the hydrocarbon emissions. Since these control options do not result in bringing the HC concentration even close to the standard, controls placed on other airport emission sources would probably not result in attainment of the standard even when coupled with the aircraft controls.

One final point should be made about the use of the AVAP model for hydrocarbon calculations. The model does not account for photochemical reactions between hydrocarbons and other pollutants. The state of the art of reactive pollutant modeling has not yet advanced to the point of being able to predict microscale dispersion patterns, nor is the macroscale predictive capability very good. Therefore, the use of a nonreactive dispersion model to simulate reactive pollutants can give useful insights providing some caveats are kept in mind. The calculated HC concentrations must be viewed only as an indicator of potential problem areas and not as absolute values. The longer the time scale and the wider the area covered by the calculation, the less valid the model will become because of the reaction rates. In this regard, the one-hour average concentration calculated here may be more meaningful than the three-hour average, which will be given later, in terms of predicted HC concentrations that might actually be observed. This exercise has its greatest value if the results can be confined to qualitative interpretation. Thus, it can be said that the calculations show a strong potential for violation of the National Ambient Air Quality Standards for hydrocarbons and none of the studied control strategies appears to be sufficient by itself to assure compliance. Only a first approximation to the relative effectiveness of the strategies could be achieved through the use of this modeling technique.

NO_x Analysis

Examination of Fig. 11a.-f. shows a different air quality pattern for NO_x than for CO and HC. Since NO_x emissions occur primarily in the takeoff, climbout, approach, and landing modes, there are areas of high concentration immediately downwind of the duty runways. The terminal area is another high NO_x concentration zone due to the large number of sources (i.e. aircraft and ground service vehicles), even though the individual source emission rates are not at their maximum in this area. It is also apparent that there is a significant contribution of NO_x from environ sources, primarily the roadways surrounding the airport. There are high concentration areas that are far-removed or upwind of any aircraft activity.

Since the National Ambient Air Quality Standard for nitrogen oxides is based on an annual average, it is not possible to compare these short-term calculations directly to the standard, except to say that several locations show calculated concentrations above the 100 $\mu g/m^3$ standard for both summer and fall conditions that could indicate potential problem areas. The annual average calculations with the long-term model will be discussed later.

As with the other pollutants, the engine shutdown and capacity control show little impact on air quality. Neither one changes the total emission rate or the spatial emission pattern enough to effect any significant air quality improvements. The towing, fleet mix control, and engine emission standards, on the other hand, generate substantial changes in the air quality picture. The emission standards provide a general concentration reduction at the runway ends but do not alleviate the terminal area problem by very much. Towing makes an impact on terminal air quality by removing all of the aircraft NO_x emissions there, but complicates the problem at the runway ends by adding the engine startup emissions to that vicinity. Fleet mix controls as shown on Table 22 create additional NO_x air quality problems because of the increased emissions from the large jumbo jet aircraft that are being incorporated into the fleet. (Recall from Table 15 that the fleet mix option increased the aircraft NO_x emissions by over 20%.) The terminal area and the runway ends experience higher NO_x concentrations under this strategy as compared to baseline conditions.

Aircraft are responsible for almost 80% of the airport NO_x emissions (see Table 14). Controls placed on other emission sources are not likely to have a large impact on the NO_x problem.

The same cautions about using a nonreactive dispersion model for a reactive pollutant as were discussed in the HC analysis apply here.

5.2.2 Worst Case Conditions

In addition to the consideration of normal seasonal meteorology, it is important to study the effect of a "worst case" situation on airport air quality. The meteorological conditions used for this analysis were modifications of the fall conditions shown on Table 19. The wind direction was maintained at 17° since this resulted in the advection of the emissions from the City of Atlanta over the airport. The wind speed was reduced to 2.0 m/sec, the atmospheric stability was increased to class 5, and the mixing height was lowered to 100 m. In addition, it was assumed that aircraft ground movements were severely impaired and long takeoff queues were formed. Queue lengths four times normal were used; this represents about 16 aircraft in the queue for runway 8/26 during the hour from 11 AM to noon.

This combination of high aircraft emission rates and poor atmospheric ventilation results in the buildup of pollutant concentrations on the airport and in the immediate environs. All of the control strategies were applied to this condition in the same manner as for the normal seasonal conditions with one exception. The engine shutdown strategy was assumed to be in effect on outbound as well as inbound aircraft. The queue lengths were long enough to extend onto controlled portions of the outbound taxiways and hence satisfied the conditions for imposition of the strategy on departing aircraft.

Figures 12-14 show the pollutant concentrations for baseline conditions and Table 23 indicates the effect of the strategies on the concentrations at the various locations. It is evident that the worst case situation results in substantial increases in pollutant concentrations at all locations. The Delta Jet Base, the Eastern hangar and the central fire station are sustaining increases in excess of 300% over normal conditions. In addition, the isopleths show substantial increases in CO and HC concentrations south of the western ends of the runways. These are due to the effects of the queues.

None of the CO readings are violating either the one-hour or eight-hour National Ambient Air Quality Standard. The hydrocarbon values are far above the standard with the worst receptor being an order of magnitude over. In general, the control strategies have a somewhat smaller relative impact on air quality under worst case conditions than under normal conditions. This is primarily a result of the increased importance of the environ emissions on air quality. It is evident from the isopleths that regions upwind of any aircraft activity are experiencing similar elevations in pollutant concentrations resulting from environ sources.

As with the normal conditions, none of the strategies is effective in insuring attainment of the ambient air quality levels specified by the national standards. With this worst case condition approaching the proportions of an air pollution episode, it would be necessary to implement some form of drastic emission reduction measures on all sources in the region to protect the public health. Clearly, the airport is not solely responsible for the high readings but is definitely a part of the problem. Application of episode control measures on airport operations, such as a suspension of activity, would have a definite impact on air quality on the airport site but might not provide for total relief unless the regional source emissions were also sharply curtailed.

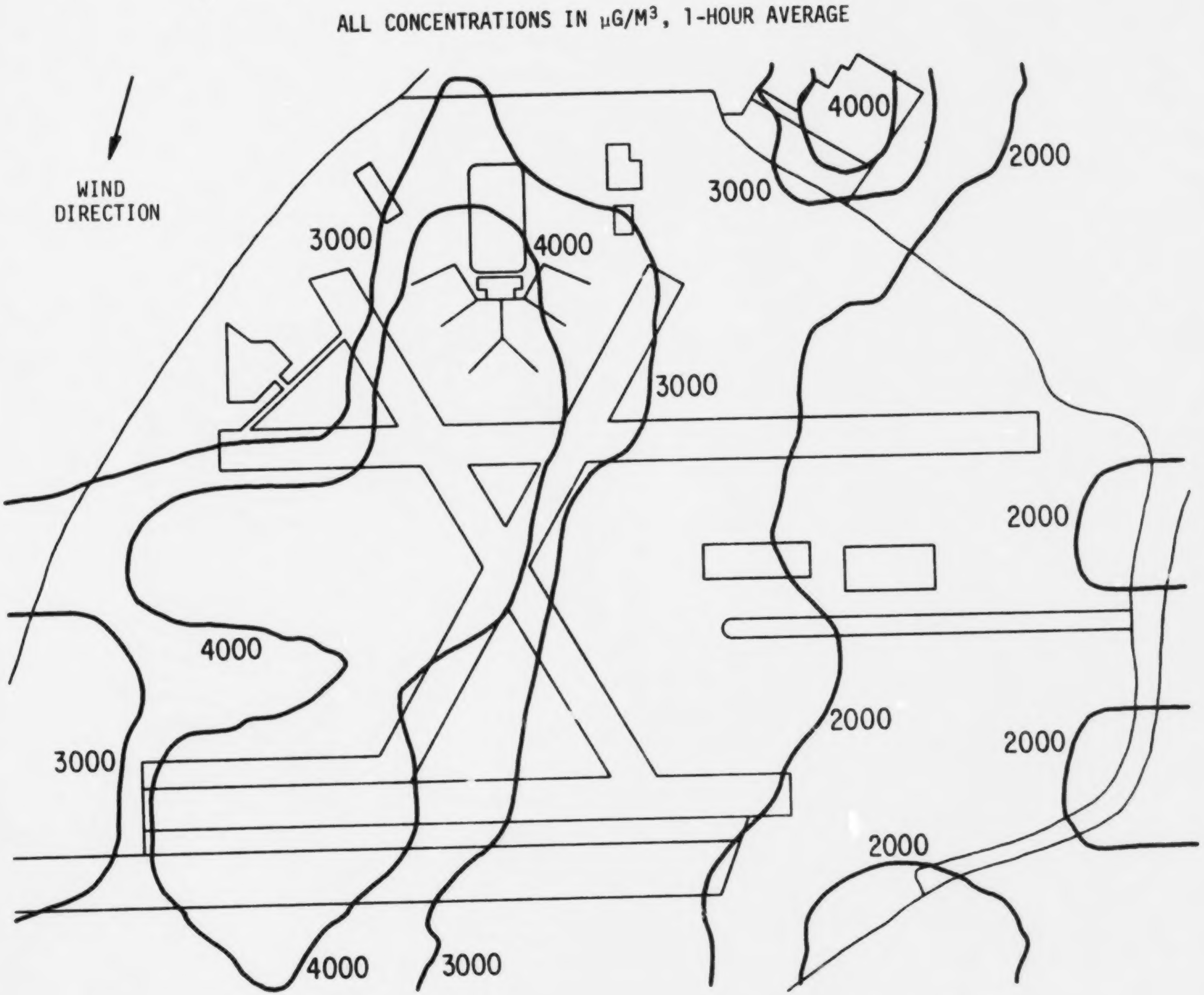
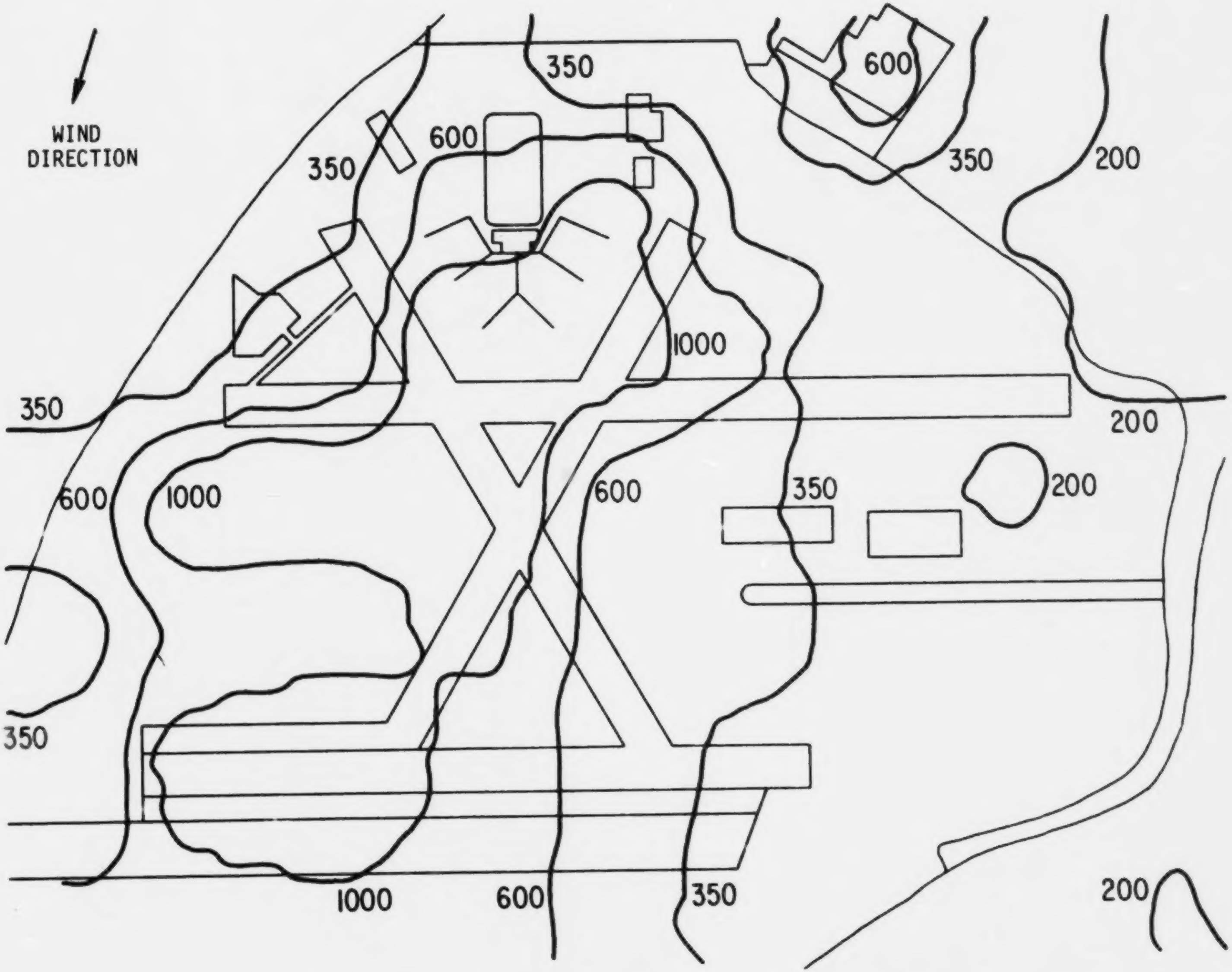

ALL CONCENTRATIONS IN μG/M³, 1-HOUR AVERAGE
WIND DIRECTION
4000
2000
3000
3000
4000
3000
2000
4000
2000
3000
2000
2000
4000
3000
2000

Fig. 12. Airport CO Concentrations for Worst Case Situation



ALL CONCENTRATIONS IN μG/M³, 1-HOUR AVERAGE

WIND DIRECTION
350
600
350
600
350
200
350
600
1000
350
600
1000
600
350
200
200
350
1000
600
350
200

Fig. 13. Airport HC Concentrations for Worst Case Situation

ALL CONCENTRATIONS IN $\mu G/M^3$, 1-HOUR AVERAGE

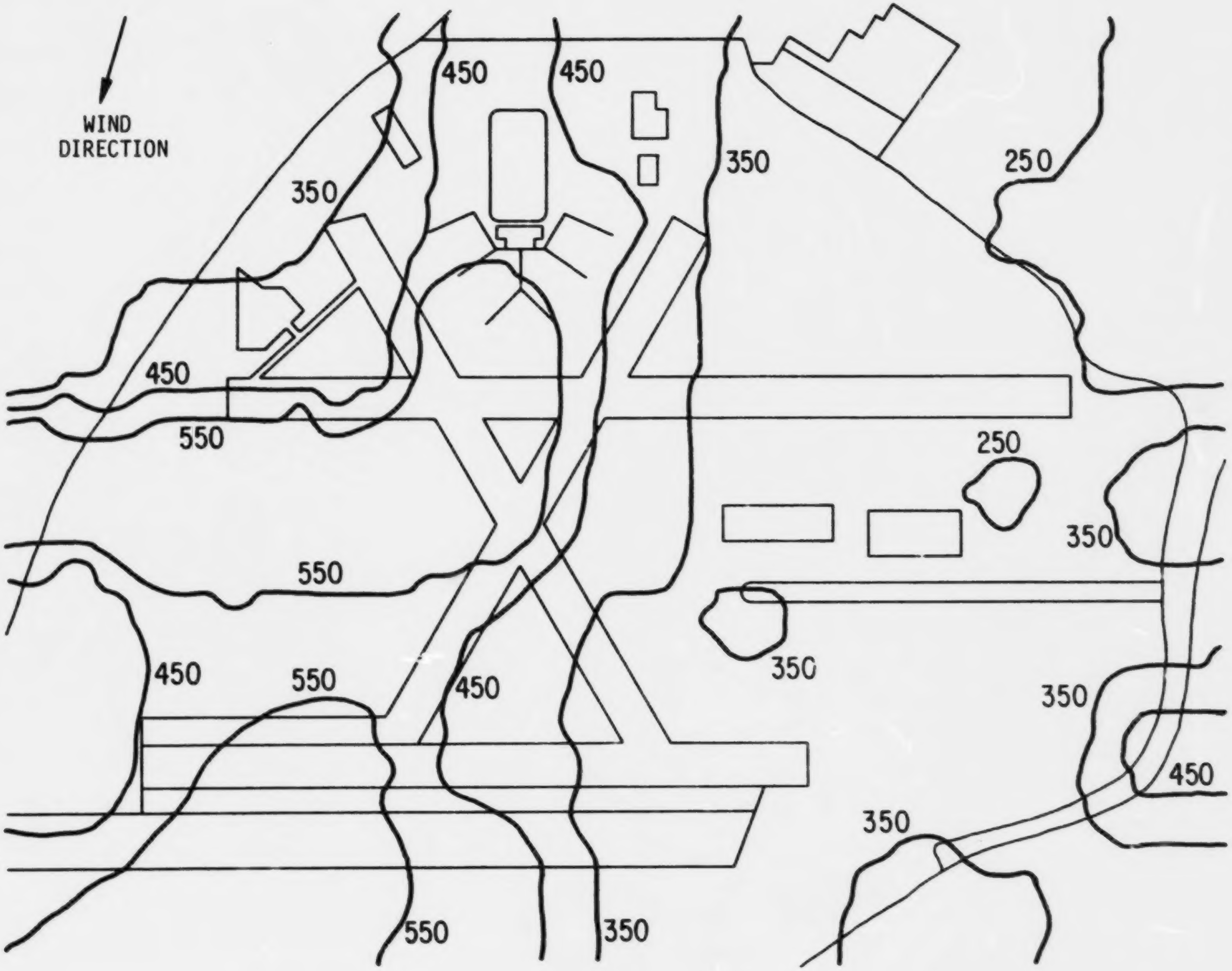

WIND
DIRECTION
450
450
350
250
350
450
550
250
350
550
450
550
450
350
350
450
350
550
350

Fig. 14. Airport NO_x Concentrations for Worst Case Situation

TABLE 23. Airport CO, HC, NO_x Concentrations for Worst Case Fall Conditions[a]

Location	Baseline	% Change Over Normal Conditions	Engine Shutdown	% Change	Towing	% Change	Capacity Control (70% LF)	% Change	Fleet Mix	% Change	Emission Standards	% Change
Terminal: Parking Lot												
CO	3982.0	+160	3982.0	0.0	3979.0	-0.1	3981.5	-0.0	3986.0	+0.1	3981.5	-0.0
HC	607.1	+127	607.1	0.0	606.6	-0.1	606.8	-0.0	608.9	+0.3	606.9	-0.0
NO_x	489.7	+193	489.5	-0.0	489.7	0.0	489.7	0.0	489.9	+0.0	489.7	0.0
Terminal: Aircraft Ramp												
CO	5759.0	+131	5721.0	-0.7	3820.5	-33.7	539[illegible].0	-6.4	3869.0	-32.8	5236.0	-9.1
HC	1432.5	+100	1405.0	-1.9	957.4	-33.2	1315.5	-8.2	845.0	-41.0	1114.2	-22.2
NO_x	578.8	+169	578.5	-0.1	477.0	-17.6	558.2	-3.6	508.4	-12.2	565.6	-2.3
Delta Jet Base												
CO	2109.8	+293	2103.3	-0.3	2114.3	+0.2	2107.3	-0.1	2111.3	+0.1	2089.8	-0.9
HC	308.0	+220	301.5	-2.1	311.2	+1.0	305.8	-0.7	295.2	-4.2	289.6	-6.0
NO_x	296.2	+340	296.2	0.0	296.3	+0.0	296.1	-0.0	297.7	+0.5	295.7	-0.2
Eastern Hangar												
CO	2405.0	+337	2405.0	0.0	2389.0	-0.7	2402.0	-0.1	2428.0	+1.0	2402.0	-0.1
HC	330.8	+183	330.8	0.0	328.3	-0.8	329.4	-0.4	341.5	+3.2	330.0	-0.2
NO_x	352.0	+321	352.0	0.0	350.7	-0.4	351.7	-0.1	352.9	+0.3	351.5	-0.1
General Aviation Hangar												
CO	2712.0	+288	2712.0	0.0	2703.5	-0.3	2711.5	-0.0	2710.5	-0.1	2703.0	-0.3
HC	339.3	+224	339.3	0.0	337.9	-0.4	339.1	-0.1	339.0	-0.1	338.9	-0.1
NO_x	426.9	+225	426.9	0.0	426.9	0.0	426.9	0.0	426.9	0.0	426.7	-0.0
Cargo Area												
CO	2385.0	+261	2385.0	0.0	2385.0	0.0	2385.0	0.0	2385.0	0.0	2385.0	0.0
HC	309.4	+239	309.4	0.0	309.4	0.0	309.4	0.0	309.4	0.0	309.4	0.0
NO_x	371.0	+243	371.0	0.0	371.0	0.0	371.0	0.0	371.0	0.0	371.0	0.0
Central Fire Station												
CO	2199.5	+382	2184.5	-0.7	2130.0	-3.2	2186.5	-0.6	2169.0	-1.4	2132.5	-3.0
HC	465.2	+184	455.5	-2.1	427.[illegible]	-8.0	459.5	-1.2	437.3	-6.0	426.8	-8.3
NO_x	330.8	+399	330.9	+0.0	327.[illegible]	-0.9	329.0	-0.5	334.4	+1.1	321.8	-2.7
Worst Receptor												
CO (#145)	8051.0	+114	8037.0	-0.2	5102.0	-36.6	7457.0	-7.4	5107.0	-36.6	7626.0	-5.3
HC (#145)	1766.0	+97	1760.0	-0.3	1322.0	-25.1	1609.0	-8.9	1149.0	-34.9	1592.0	-9.9
NO_x (#130)	908.3	+101	908.9	+0.1	789.4	-13.1	843.5	-7.1	982.8	+8.2	736.4	-18.9

[a] All concentrations in $\mu g/m^3$, 1-hr average.

6.0 STRATEGY IMPACT ON REGIONAL AIR QUALITY

This section will deal with the airport's impact on regional air quality and the effectiveness of each of the control strategies in reducing adverse effects.

6.1 EMISSIONS

As was previously discussed, the emission inventory for the Atlanta area was assembled from the point source file of the Georgia Department of Natural Resources and from an area source inventory generated from census data and traffic information from the Georgia Highway Department. The point source file covered the 10-county area surrounding the airport. The area source emissions were displayed on a grid extending to 20 km from the airport boundaries. The grid square sizes were chosen to match the resolution of the available data. Figure 15 shows the grid arrangement. The interstate highways surrounding the airport were modeled as line sources rather than area sources to improve the spatial resolution of the emission pattern.

Table 24 shows the breakdown of environ emissions by source. Table 25 gives the contribution of the airport emissions to the regional total under baseline and alternative strategy conditions. It is evident that the airport makes a contribution in the vicinity of 3-4% to the regional CO, HC, and NO_x emissions. Regionwide, CO emissions come predominantly from transportation sources (i.e., motor vehicles). The airport's contribution amounts to about half of the total of the point sources. Hydrocarbon emissions originate mostly from motor vehicles and evaporative sources (e.g., gasoline marketing, dry-cleaning, solvent use). The airport contributes twice as much HC as the point sources. This may be a result of the lack of any significant HC-producing industries in the region (e.g., chemical processing facilities). For NO_x, the point sources and motor vehicles dominate and the airport is roughly equivalent to the space heating sources. In light of this emission comparison, the airport represents a significant concentration of sources. The engine emission standards have the greatest effect on regional emission loads, as shown on Table 25.

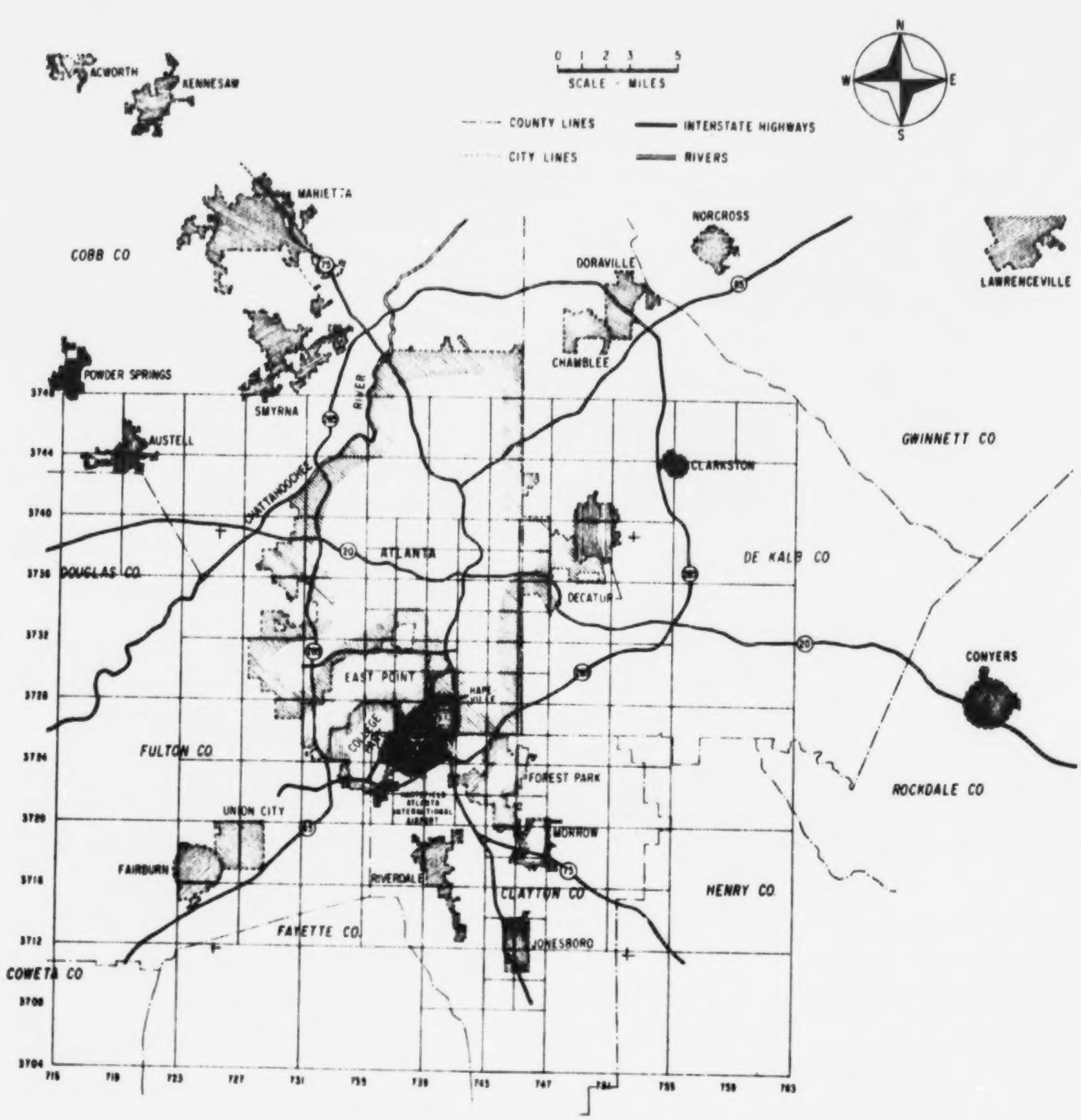

0 1 2 3 5
SCALE - MILES
N
W
E
S
COUNTY LINES
INTERSTATE HIGHWAYS
CITY LINES
RIVERS
ACWORTH
KENNESAW
MARIETTA
NORCROSS
LAWRENCEVILLE
COBB CO
DORAVILLE
CHAMBLEE
POWDER SPRINGS
SMYRNA
RIVER
GWINNETT CO
AUSTELL
CLARKSTON
CHATTAHOOCHEE
ATLANTA
DE KALB CO
DOUGLAS CO
DECATUR
CONYERS
EAST POINT
HAPEVILLE
COLLEGE PARK
FULTON CO
FOREST PARK
ROCKDALE CO
UNION CITY
ATLANTA INTERNATIONAL AIRPORT
MORROW
FAIRBURN
RIVERDALE
CLAYTON CO
HENRY CO
FAYETTE CO
JONESBORO
COWETA CO
75
85
20
3748
3744
3740
3736
3732
3728
3724
3720
3716
3712
3708
3704
715
719
723
727
731
735
739
743
747
751
755
759
763

Fig. 15. Grid System for Inventorying Environ Area Sources

TABLE 24. Atlanta Region Emission Inventory

Source	Emissions (10^3 metric tons/yr) CO	HC	NO_x
Point Sources[a]	11.2	1.6	26.4
Area Sources[b]			
Transportation[c]	233.5	28.4	32.9
Space Heating[d]	.4	0.1	2.5
Refuse Disposal[e]	12.1	4.6	1.7
Evaporation[f]		41.4	
Line Sources[g]	6.8	0.9	2.2
Airport[h]	8.6	3.5	2.6
Regional Total	272.6	80.5	68.3

[a] For 10-county region

[b] Extending to 20 km from the airport boundary

[c] Excluding the airport

[d] Residential, commercial/institutional, and industrial

[e] Open burning and on-site incineration

[f] Drycleaning and solvent use

[g] Roadways surrounding the airport

[h] Baseline conditions

TABLE 25. Contribution of Airport Emissions to the Regional Total

Strategy	Airport % of Regional Emissions CO	HC	NO_x
Baseline	3.2	4.3	3.9
Engine shutdown	3.1	4.3	3.9
Towing	2.3	2.9	3.9
Capacity Control (70% LF)	2.9	4.0	3.5
Fleet mix	2.4	2.7	4.7
Engine emission standards	2.0	2.2	2.3

6.2 AIR QUALITY IMPACTS

6.2.1 Normal Conditions

Of special interest to the analysis of the airport's regional impact is the extent of influence of the airport sources alone on air quality. Figures 16-18 attempt to answer this by displaying isopleths that have been calculated using only the airport emission sources. All other sources have been zeroed. The fall and summer meteorological parameters are the same as the normal conditions used in Section 5.0.

The first point of interest in the figures is the limited lateral extent of the airport's influence. Concentrations drop off rapidly with distance perpendicular to the wind line. The lack of substantial crosswind spreading implies that the airport has very little influence on areas that are not directly downwind of it. The fact that the high concentration areas are larger for fall conditions than for summer conditions is due to the lower mixing height in fall (see Table 19).

For CO, the airport does not appear to be creating any regional problems in attainment of the National Ambient Air Quality Standard. This is consistent with the previous evaluation of airport air quality, which also showed no CO problem. For hydrocarbons, the airport sources alone are close to causing a violation of the 160 $\mu g/m^3$ standard under summer conditions and do result in an excess under fall conditions. It should be reemphasized that the standard is written for a three-hour averaging time from 6-9 AM and these calculations are for one-hour between 11 AM and 12 noon. Nevertheless, there are indications that the combination of airport and environ emissions might result in a violation of the hydrocarbon standard. The three-hour average calculations (which will be discussed later) do, in fact, confirm this. For NO_x, the airport is contributing a little less than half of the 100 $\mu g/m^3$ annual standard under both summer and fall conditions.

Regional pollutant levels from all sources in the emission inventory are displayed on Figs. 19-21. Under summer conditions with the wind from the southwest quadrant, the airport lies downwind of a relatively undeveloped area with little emission activity. Consequently, pollutant concentrations are low upwind of the airport and increase sharply at the airport site and beyond. The high concentrations calculated in the vicinity of Hapeville are, to some

ALL CONCENTRATIONS IN μG/M³, 1-HOUR AVERAGE

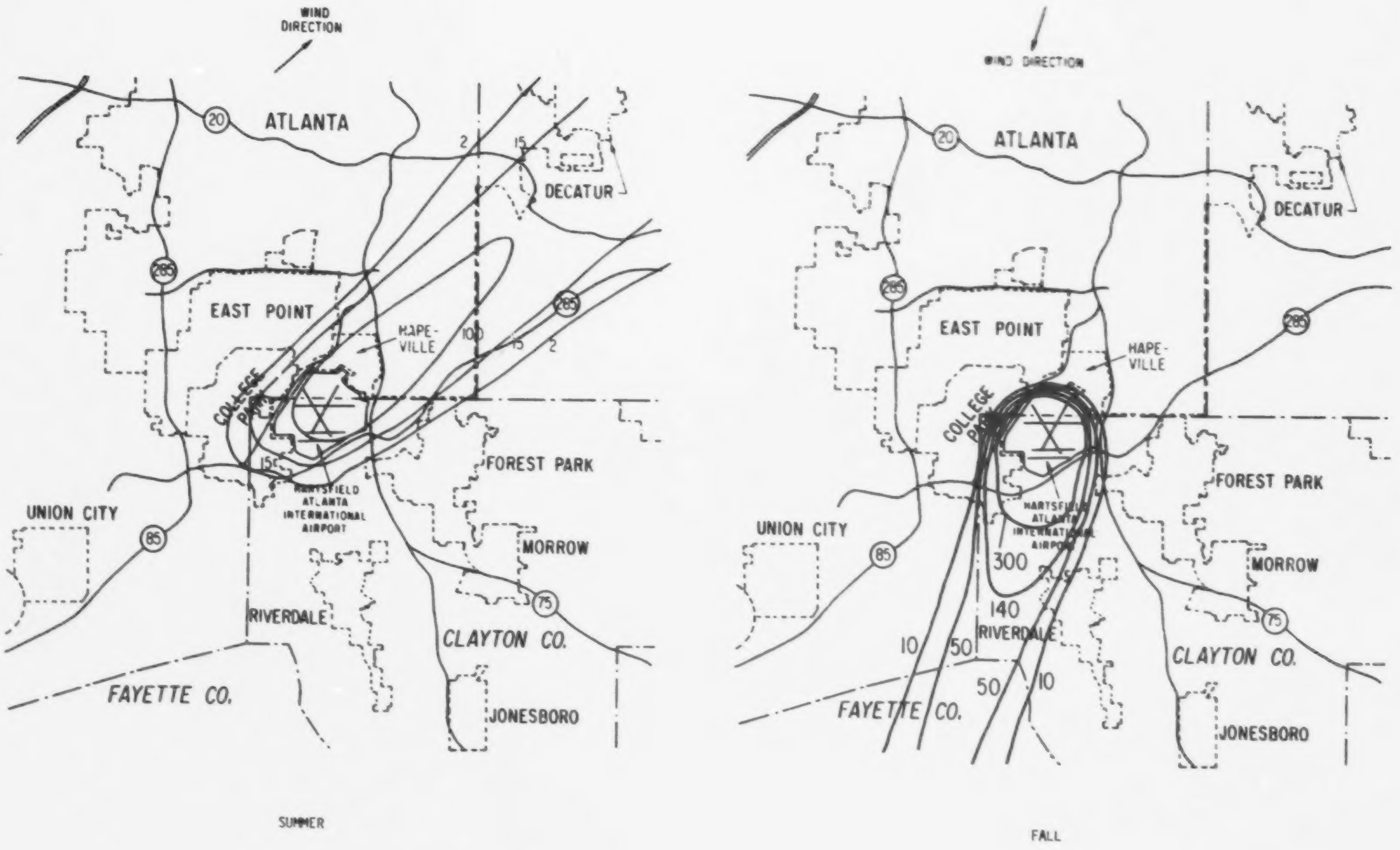

WIND DIRECTION
ATLANTA
20
DECATUR
285
EAST POINT
HAPE-VILLE
COLLEGE PARK
2
15
100
15
2
15
HARTSFIELD ATLANTA INTERNATIONAL AIRPORT
UNION CITY
85
FOREST PARK
MORROW
75
RIVERDALE
CLAYTON CO.
FAYETTE CO.
JONESBORO
SUMMER
WIND DIRECTION
ATLANTA
20
DECATUR
285
EAST POINT
HAPE-VILLE
COLLEGE PARK
HARTSFIELD ATLANTA INTERNATIONAL AIRPORT
UNION CITY
85
FOREST PARK
MORROW
300
140
RIVERDALE
10
50
50
10
75
CLAYTON CO.
FAYETTE CO.
JONESBORO
FALL

Fig. 16. Regional Impact of CO Emissions from Airport Sources Alone Under Baseline Conditions

ALL CONCENTRATIONS IN µG/M³, 1-HOUR AVERAGE

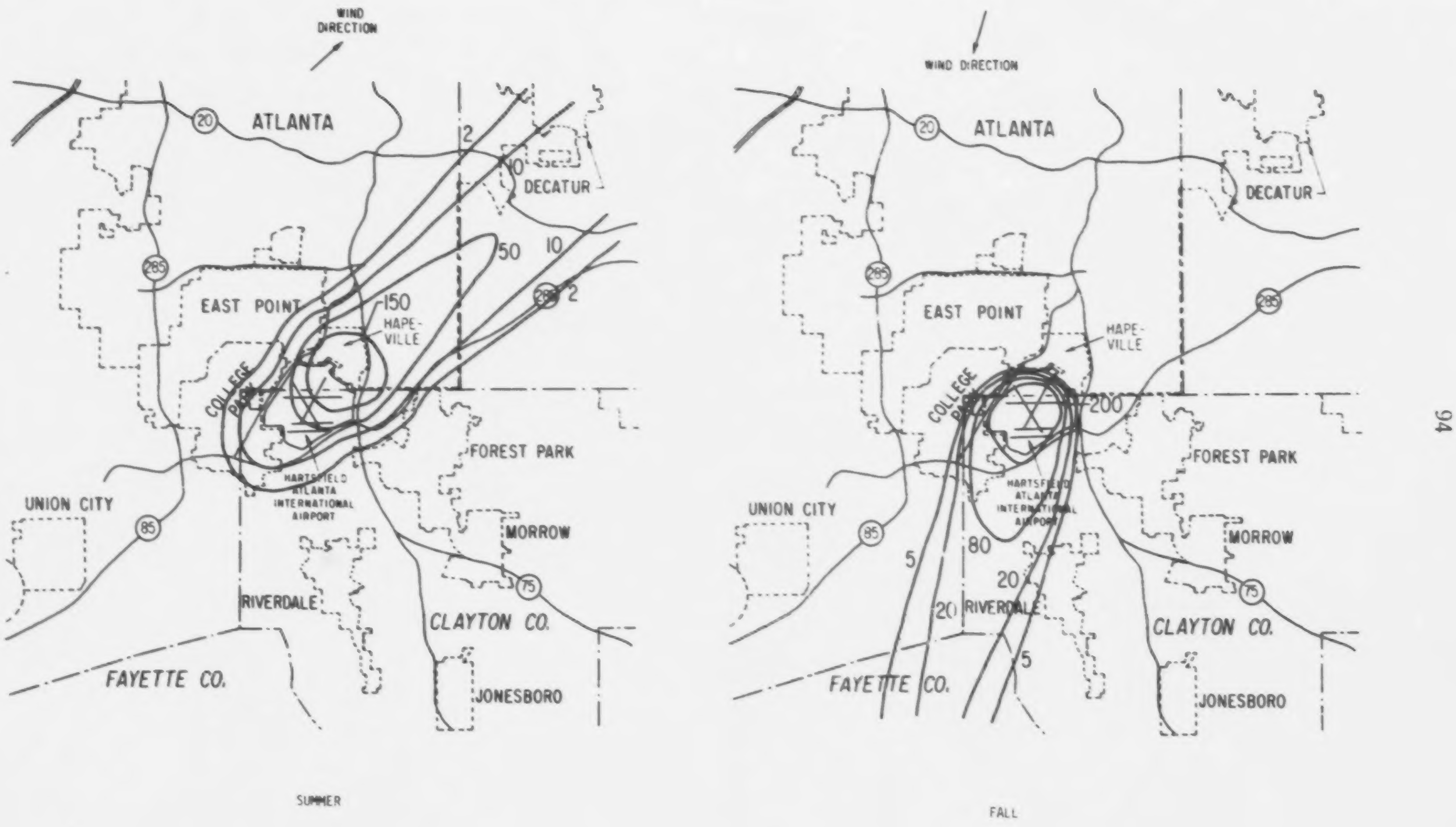

WIND DIRECTION
ATLANTA
DECATUR
EAST POINT
HAPE-VILLE
COLLEGE PARK
HARTSFIELD ATLANTA INTERNATIONAL AIRPORT
FOREST PARK
UNION CITY
MORROW
RIVERDALE
CLAYTON CO.
FAYETTE CO.
JONESBORO
20
285
85
75
2
10
50
150
SUMMER
WIND DIRECTION
ATLANTA
DECATUR
EAST POINT
HAPE-VILLE
COLLEGE PARK
HARTSFIELD ATLANTA INTERNATIONAL AIRPORT
200
FOREST PARK
UNION CITY
MORROW
80
20
5
RIVERDALE
CLAYTON CO.
FAYETTE CO.
JONESBORO
FALL

Fig. 17. Regional Impact of HC Emissions from Airport Sources Alone Under Baseline Conditions

ALL CONCENTRATIONS IN $\mu G/M^3$, 1-HOUR AVERAGE

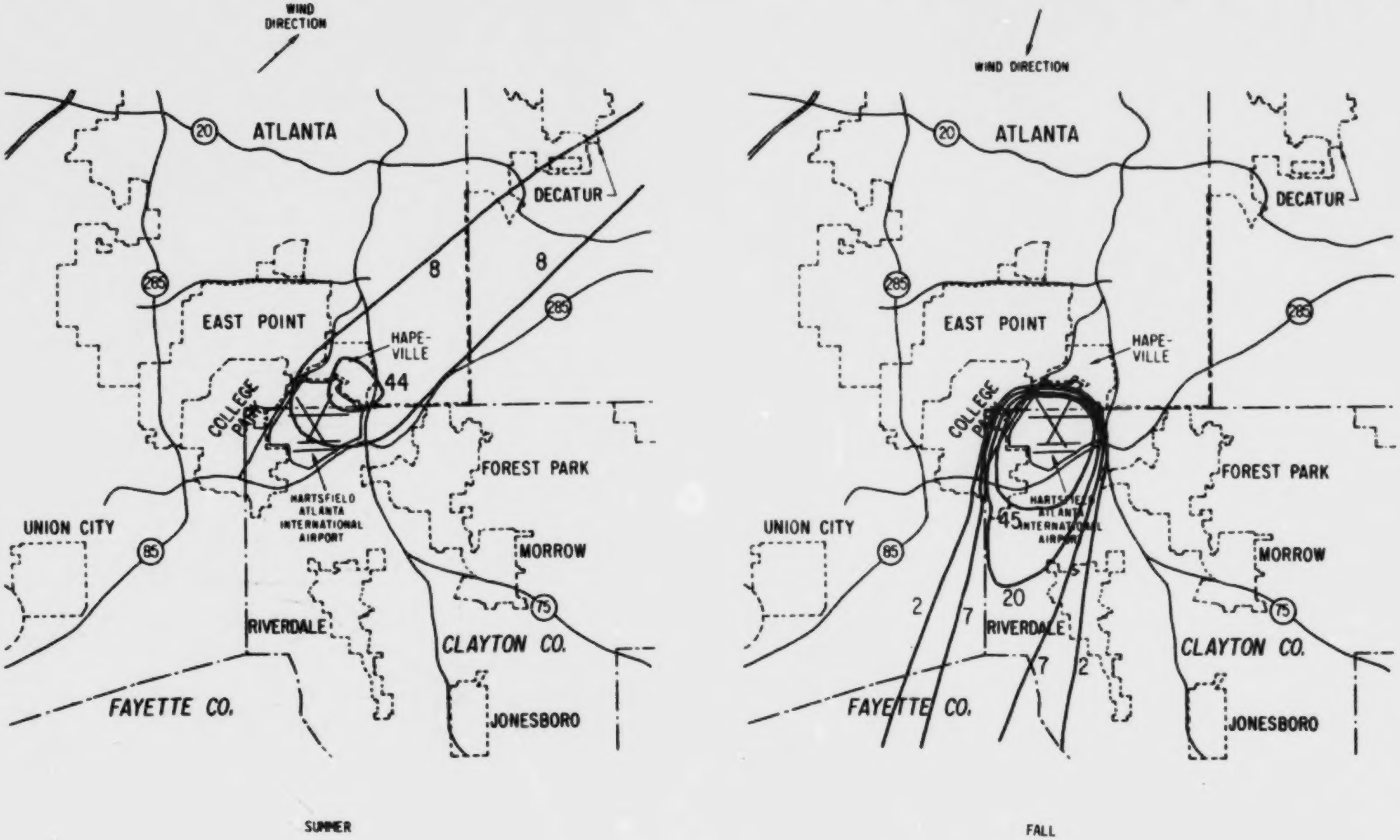

WIND DIRECTION
ATLANTA
DECATUR
EAST POINT
HAPE-VILLE
COLLEGE PARK
FOREST PARK
HARTSFIELD ATLANTA INTERNATIONAL AIRPORT
UNION CITY
MORROW
RIVERDALE
CLAYTON CO.
FAYETTE CO.
JONESBORO
20
285
85
75
8
8
44
SUMMER
WIND DIRECTION
ATLANTA
DECATUR
EAST POINT
HAPE-VILLE
COLLEGE PARK
FOREST PARK
HARTSFIELD ATLANTA INTERNATIONAL AIRPORT
UNION CITY
MORROW
RIVERDALE
CLAYTON CO.
FAYETTE CO.
JONESBORO
20
285
85
75
45
5
20
2
7
7
2
FALL

Fig. 18. Regional Impact of NO_x Emissions from Airport Sources Alone Under Baseline Conditions

ALL CONCENTRATIONS IN µG/M³, 1-HOUR AVERAGE

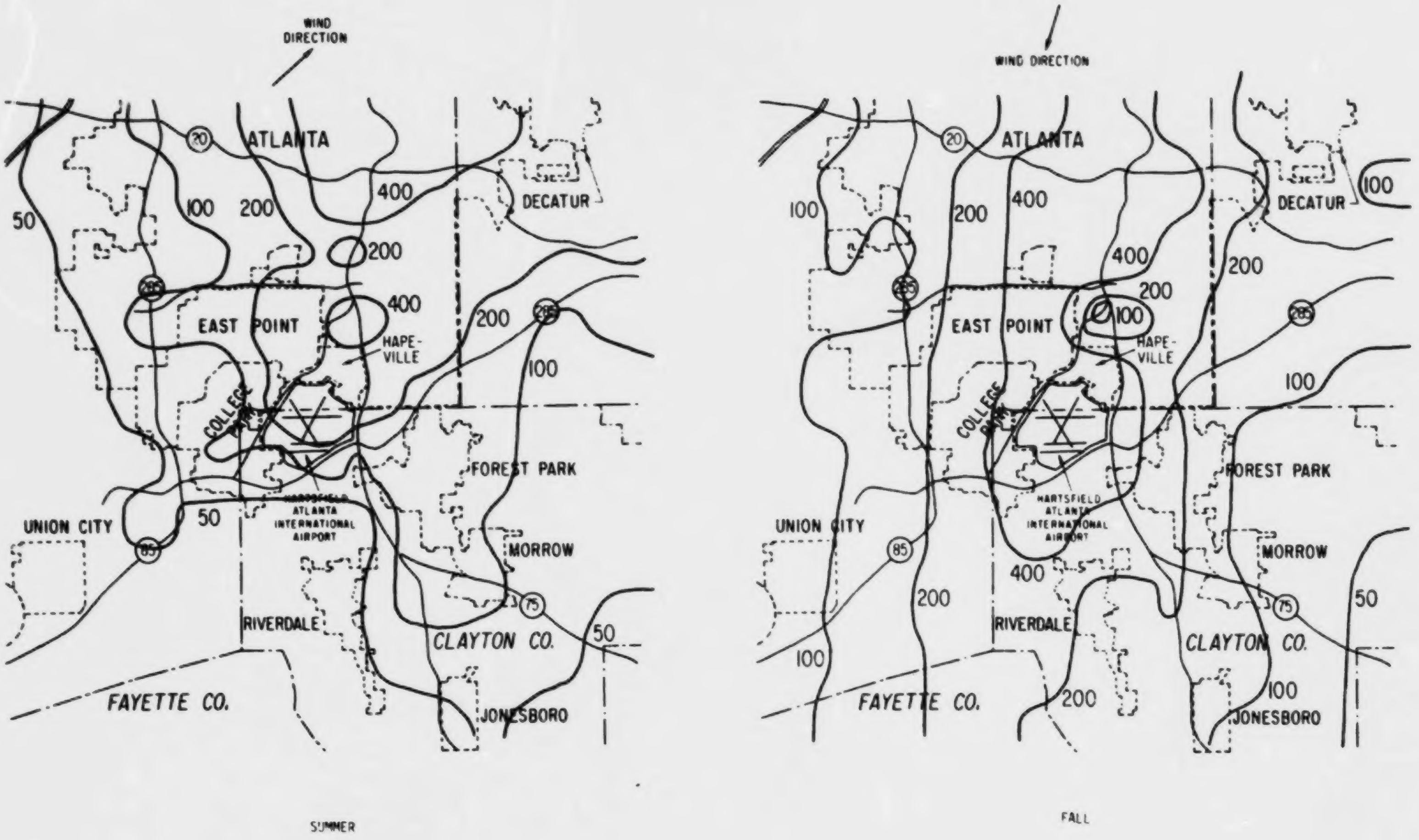

WIND DIRECTION
ATLANTA
DECATUR
EAST POINT
HAPE-VILLE
COLLEGE PARK
FOREST PARK
HARTSFIELD ATLANTA INTERNATIONAL AIRPORT
UNION CITY
MORROW
RIVERDALE
CLAYTON CO.
FAYETTE CO.
JONESBORO
20
285
85
75
50
100
200
400
SUMMER
WIND DIRECTION
ATLANTA
DECATUR
EAST POINT
HAPE-VILLE
COLLEGE PARK
FOREST PARK
HARTSFIELD ATLANTA INTERNATIONAL AIRPORT
UNION CITY
MORROW
RIVERDALE
CLAYTON CO.
FAYETTE CO.
JONESBORO
20
285
85
75
50
100
200
400
FALL

Fig. 19. Regional CO Concentrations Under Baseline Conditions

ALL CONCENTRATIONS IN $\mu G/M^3$, 1-HOUR AVERAGE

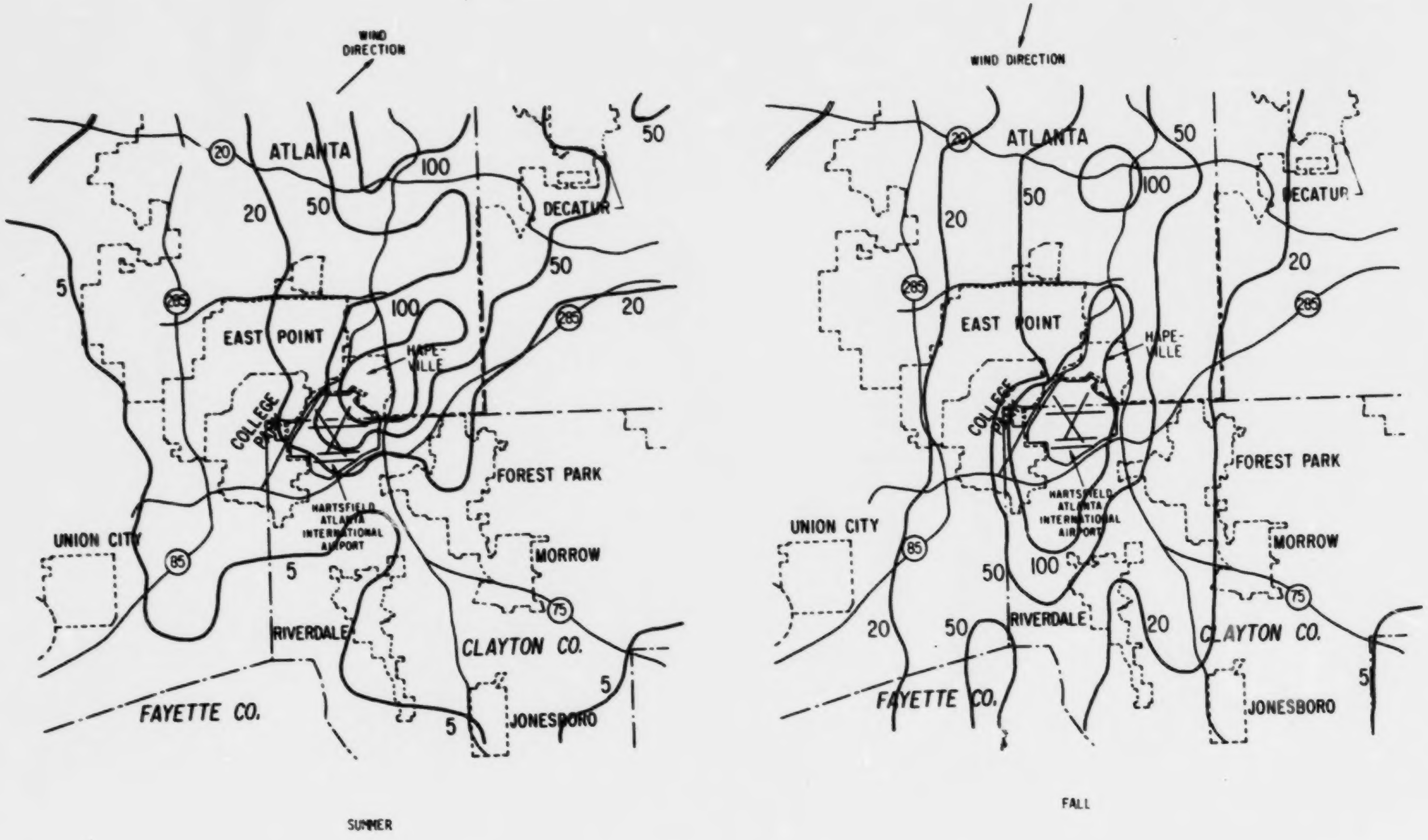
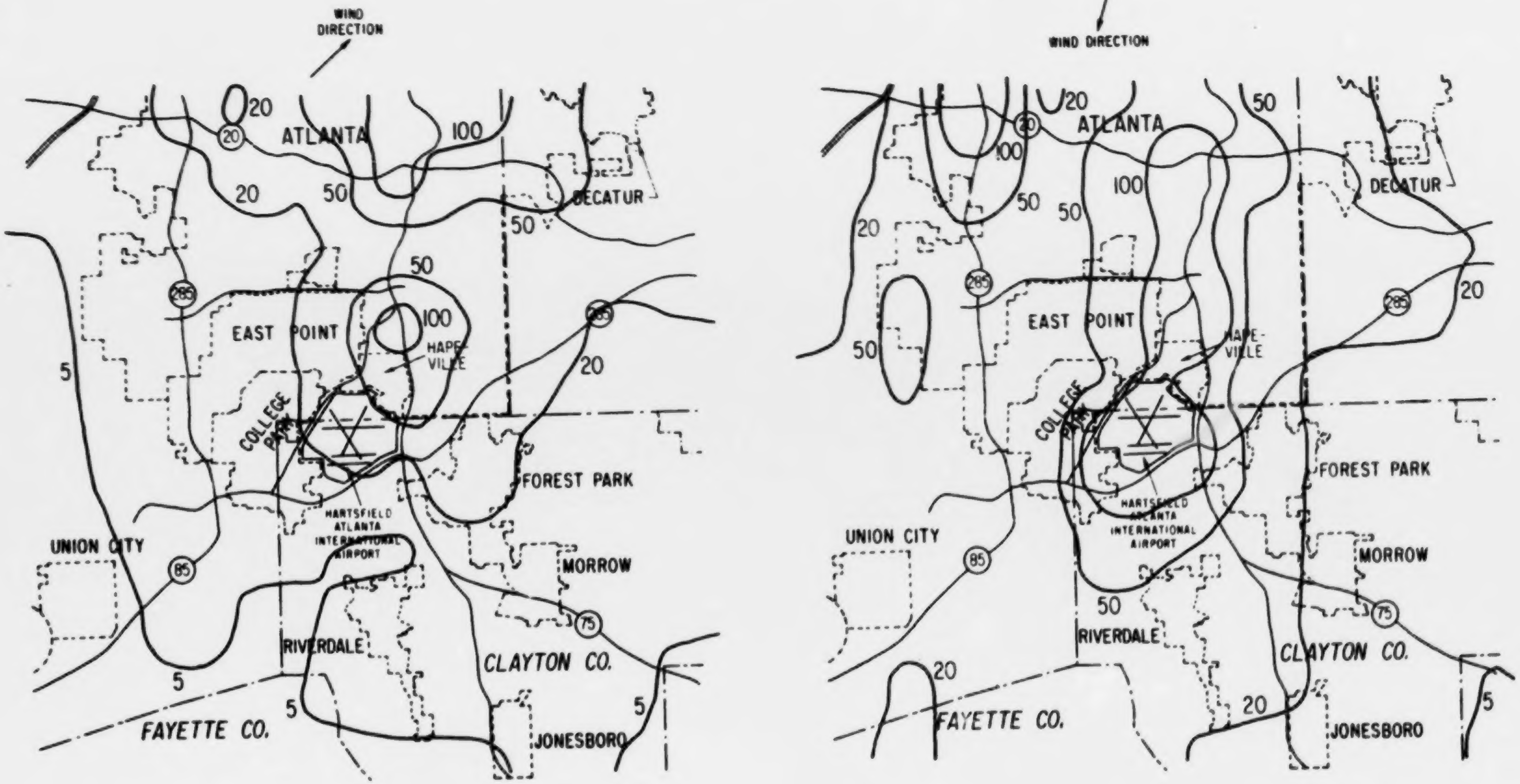

WIND DIRECTION
ATLANTA
DECATUR
EAST POINT
HAPE-VILLE
COLLEGE PARK
HARTSFIELD ATLANTA INTERNATIONAL AIRPORT
FOREST PARK
UNION CITY
MORROW
RIVERDALE
CLAYTON CO.
FAYETTE CO.
JONESBORO
20
285
85
75
5
20
50
100
SUMMER
FALL

Fig. 20. Regional HC Concentrations Under Baseline Conditions

ALL CONCENTRATIONS IN µG/M³, 1-HOUR AVERAGE


WIND DIRECTION
ATLANTA
DECATUR
EAST POINT
HAPEVILLE
COLLEGE PARK
HARTSFIELD ATLANTA INTERNATIONAL AIRPORT
FOREST PARK
UNION CITY
MORROW
RIVERDALE
CLAYTON CO.
FAYETTE CO.
JONESBORO
20
285
85
75
5
20
50
100
WIND DIRECTION
ATLANTA
DECATUR
EAST POINT
HAPEVILLE
COLLEGE PARK
HARTSFIELD ATLANTA INTERNATIONAL AIRPORT
FOREST PARK
UNION CITY
MORROW
RIVERDALE
CLAYTON CO.
FAYETTE CO.
JONESBORO
20
50
100

SUMMER FALL

Fig. 21. Regional NO_x Concentrations Under Baseline Conditions

degree, a result of the intersection of Interstate Highways 75 and 85, which are modeled as line sources. The southwest wind moves almost parallel to I-85 and concentrates the emissions from the entire length of the line segment, thereby creating the hot spots shown on the map.

Under fall conditions the airport is downwind of the Atlanta central business district (CBD) and several other neighboring urban areas. Consequently, there is a significant quantity of emissions being transported across the airport and into the surrounding areas to the south.

It is evident that under both summer and fall conditions the high concentration zones in the vicinity of the airport are of the same order of magnitude as those in the vicinity of the Atlanta CBD, although generally not as extensive in area. It can therefore be stated that the airport is roughly equivalent to the CBD in terms of its emission density and corresponding impact on regional air quality.

Another means of describing the airport's contribution to regional air quality is to determine the effect of airport sources on pollutant concentrations along a line parallel to the wind direction and extending both up- and downwind of the airport. As previously indicated on Figs. 16-18, this will represent the maximum impact since the lateral spread of pollutants perpendicular to the wind is extremely limited for the airport sources. Figures 22 and 23 show plots of calculated concentrations along the wind line that runs through the airport location point (ALP). (The ALP is a geometric code point used to identify general airport locations in a national perspective. The Atlanta airport ALP is located at the intersection of taxiways C and D in approximately the center of the field as shown on Fig. 2.) No attempt was made to include the airport concentrations on the figures, as the detailed modeling carried out makes the calculated concentration very sensitive to receptor location and the results might present a distorted picture of the actual situation.

Concentration profiles in Fig. 22 emphasize the low level of pollutants southwest of the airport that was discussed previously. Total concentrations begin to rise about 2 km upwind of the ALP, where modeled freeway segments produce a rise in concentrations from environ sources and inbound taxiing by aircraft landing on runway 27L causes the first appearance of airport pollutants. Receptors upwind of the ALP are spaced at 2 km, hence fail

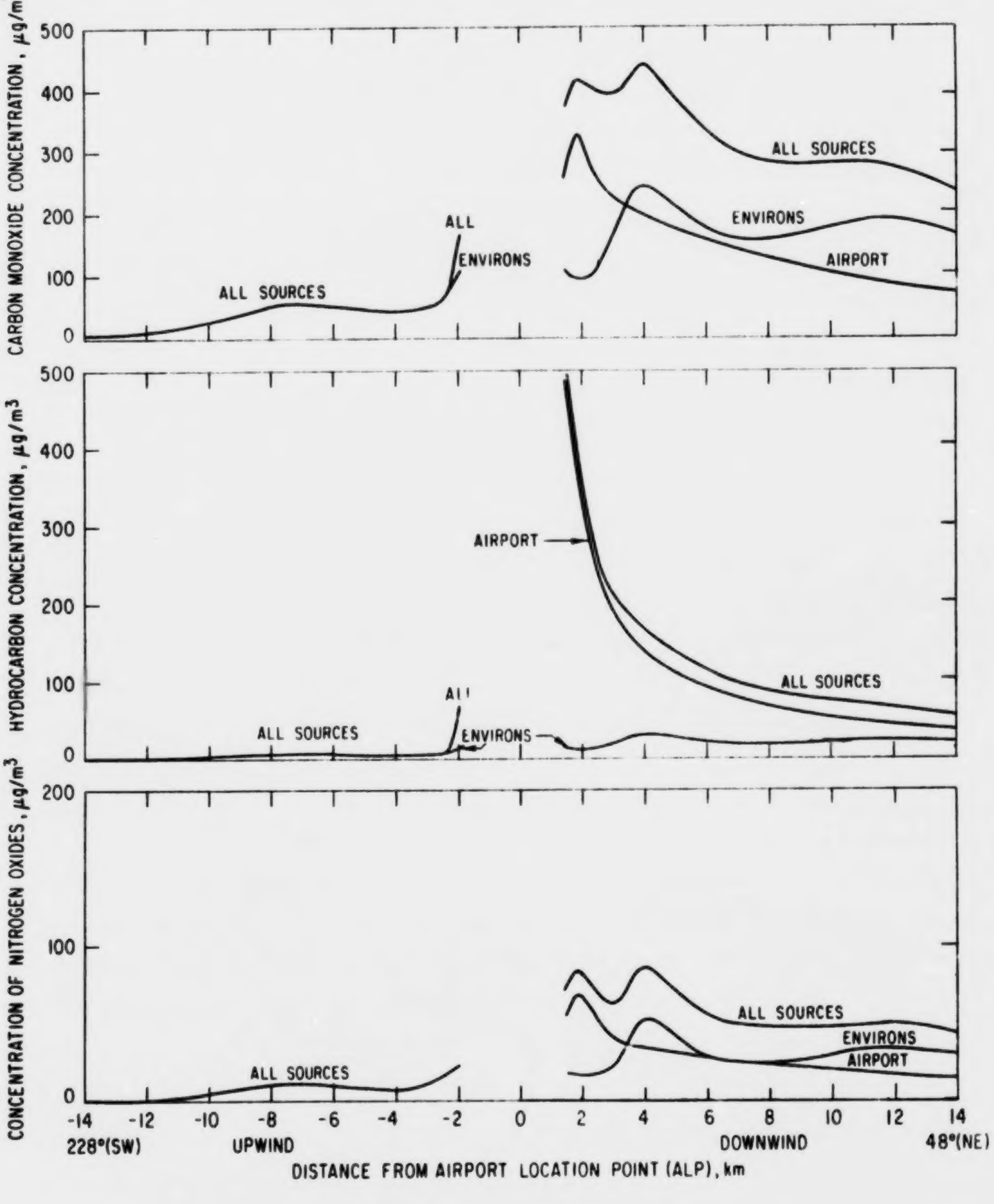


Fig. 22. Wind Line Pollutant Profiles Under Baseline Conditions, Summer

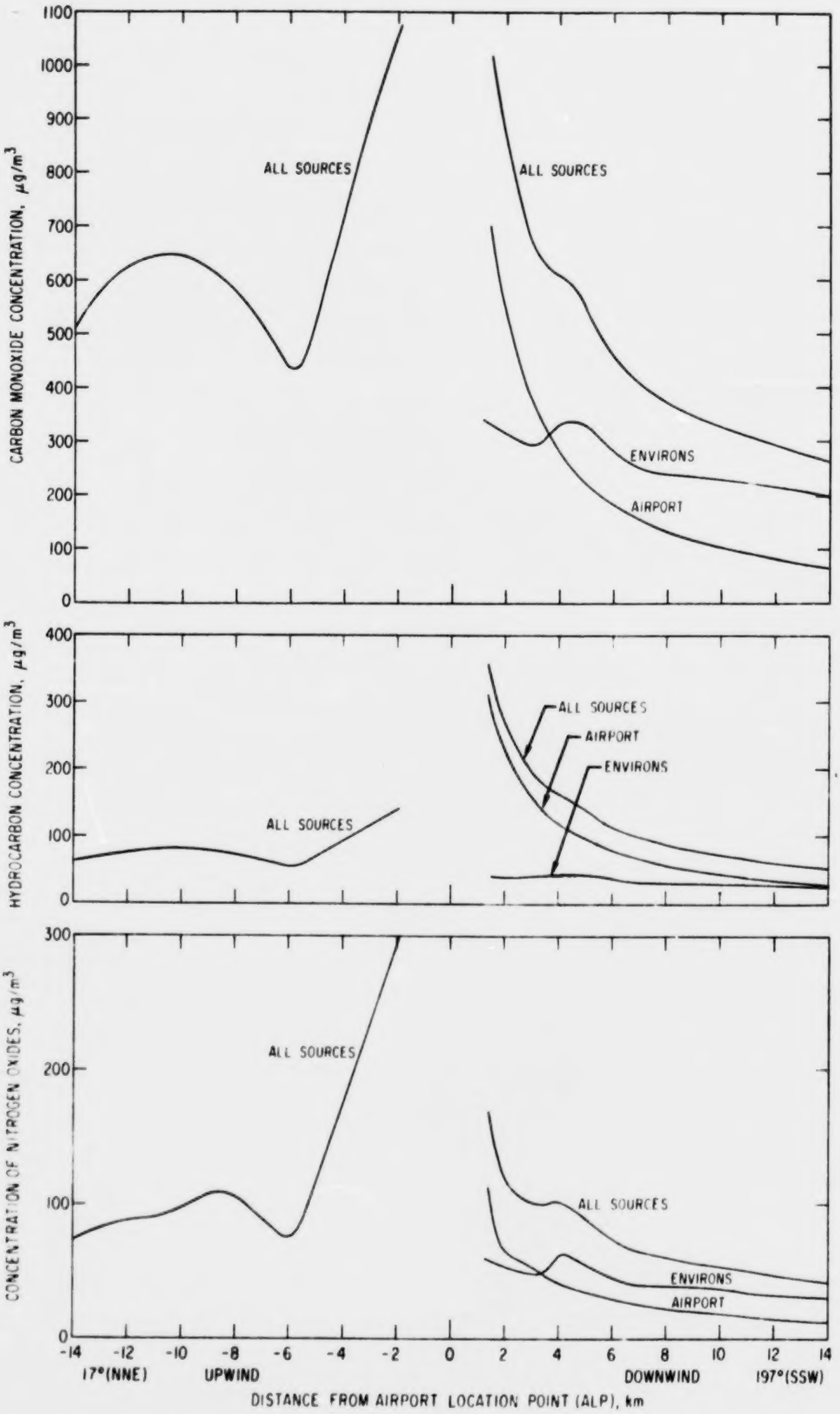


Fig. 23. Wind Line Pollutant Profiles Under Baseline Conditions, Fall

to pick up fine structure of the profiles near concentrated sources such as roadway and taxiway lines. Downwind receptors are 1.5 km, 2 km, 3 km, and 4 km from the ALP and then are spaced at every 2 km beyond. The peaks in concentrations from airport sources 2 km from the ALP come where the wind vector crosses the remote parking lots northeast of the terminal. The environ peaks at 4 km are due to the I-75 expressway segments east of Hapeville. The broad peaks in environ concentrations at about 12 km from the ALP correspond to the general buildup in source densities for areas nearer the center of Atlanta. Decatur is slightly beyond the ends of the curves displayed at approximately 16 km from the ALP.

The airport produces less than half of the calculated total carbon monoxide concentrations at receptors farther than 3-1/2 km from the ALP; it produces less than half of the nitrogen oxides beyond 8 km; but it causes more than half of the calculated hydrocarbon concentration even at 14 km from the airport. At 14 km, airport sources cause 30% of the calculated carbon monoxide concentration, 32% of the nitrogen oxide concentration, and 62% of the hydrocarbon concentration.

With the wind from the north-northeast, as in Fig. 23, central Atlanta sources produce broad peaks in the pollutant concentration profiles upwind of the airport. A steep, almost linear rise in all profiles beginning at -6 km is a happenstance due to almost exact coincidence of the line of receptors with modeled segments of I-85; the concentrations rise quickly as more of the roadway length is located upwind of receptor sites. Concentrations from line sources decay sharply with distance from the line, as shown by return of environ concentrations to more modest values downwind of the airport. The environ peaks between 4 and 5 km downwind of the airport are from I-285, crossed here perpendicularly, in contrast to the tangential encounter with I-85. Relatively large pollutant levels from environ sources in Atlanta are sustained downwind of the airport, where few additional sources are available to augment the levels. Airport sources cause high pollutant levels near the airport that decrease smoothly with distance.

Airport contributions to carbon monoxide and nitrogen oxide total concentrations drop off to less than half the total within a short distance. Once again, however, the airport produces more than half the calculated total hydrocarbon concentration, even at 14 km from the airport. At 14 km, airport contributions to carbon monoxide, hydrocarbon, and nitrogen oxide concentrations are 25%, 52%, and 28%, respectively.

The same general considerations regarding the impact of airport sources on the attainment of the National Ambient Air Quality Standards that were discussed under the airport impact analysis carry over to the regional considerations. That is, there does not appear to be any problem with CO; the hydrocarbon concentrations show a definite potential for standard violation; and the one-hour NO_x concentrations are near the annual average standard, but no definite statement can be made without the long-term modeling results.

It must be reemphasized that these evaluations apply to the line of maximum airport impact. Small displacements perpendicular to the wind line result in substantial reductions in pollutant concentrations resulting from airport sources.

The impact of each of the control strategies on regional air quality is shown on Figs. 24-26. As would be expected, each strategy shows maximum impact close to the airport and the distinctions between each strategy diminish with distance. Nevertheless there is a discernible difference in impact among the control options as far away as 14 km from the ALP.

An interesting observation can be made about the comparison between the strategy impact on the wind line profile and on the airport emissions (Table 15). For CO and HC the strategies "line up" in the same relative order of effectiveness on the wind line profile as they do on emissions. The exception is the towing strategy, which affords the greatest impact on wind line concentrations but is second in terms of emission reduction behind the emission standards. At 6 km from the ALP under fall conditions, the towing strategy results in a 23% reduction in CO concentration as compared to 15% for the engine emission standards. This is the same effect as was described in the airport evaluation; that is, the towing strategy changes the spatial emission pattern enough to realize a greater air quality improvement than would be expected from the emission change alone. The evaluation of the wind line profiles shows this effect is felt even far downwind of the airport.

For NO_x, the increase in emissions resulting from the fleet mix option is evident downwind as far as 14 km. As before, the engine emission standards offer the greatest reductions in NO_x concentrations.

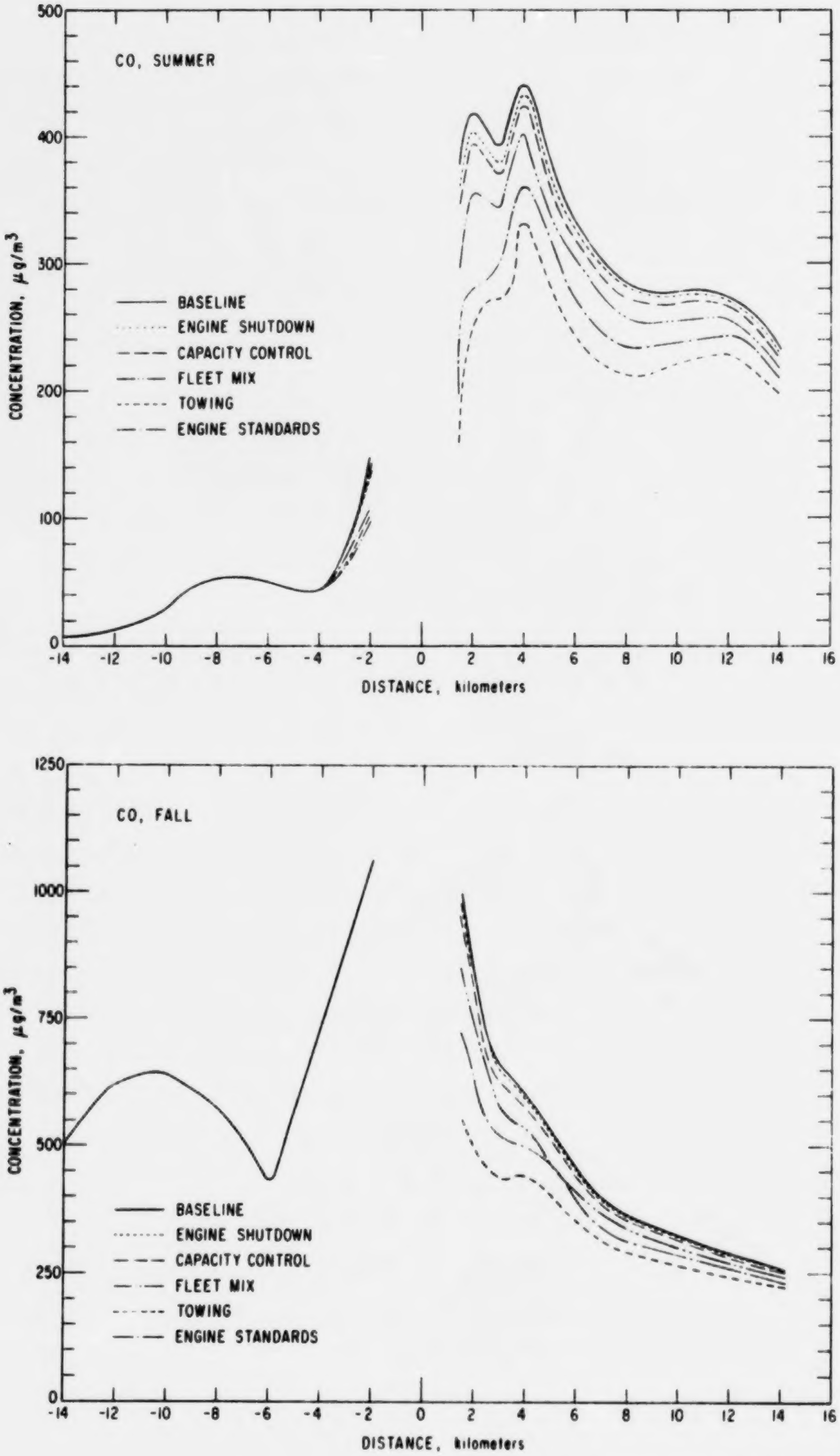
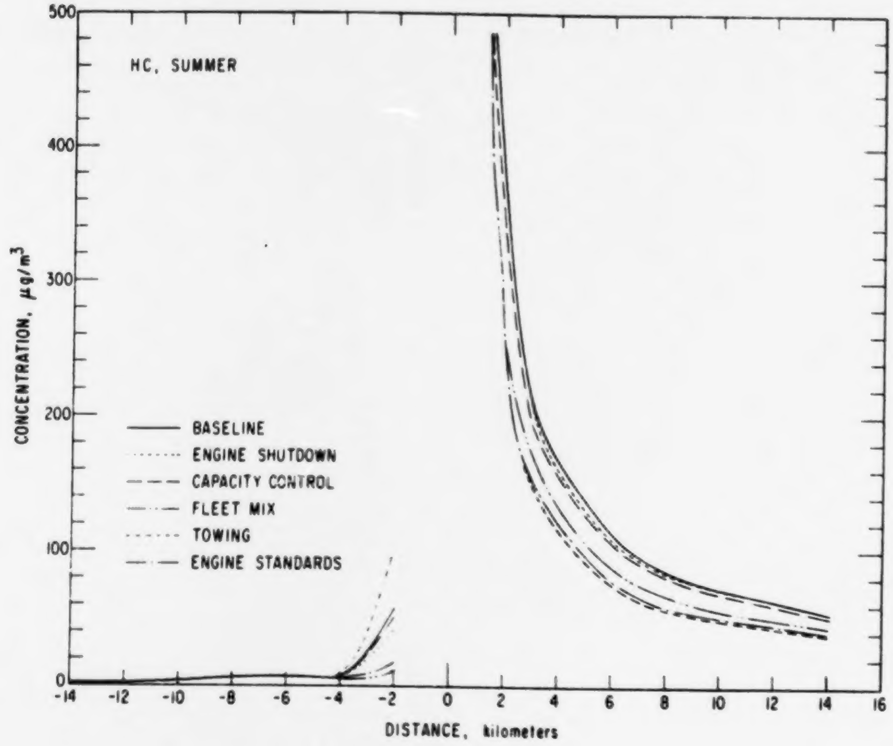


Fig. 24. Strategy Impact on Wind Line CO Profiles



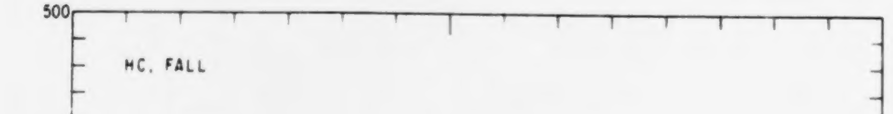


Fig. 25. Strategy Impact on Wind Line HC Profiles

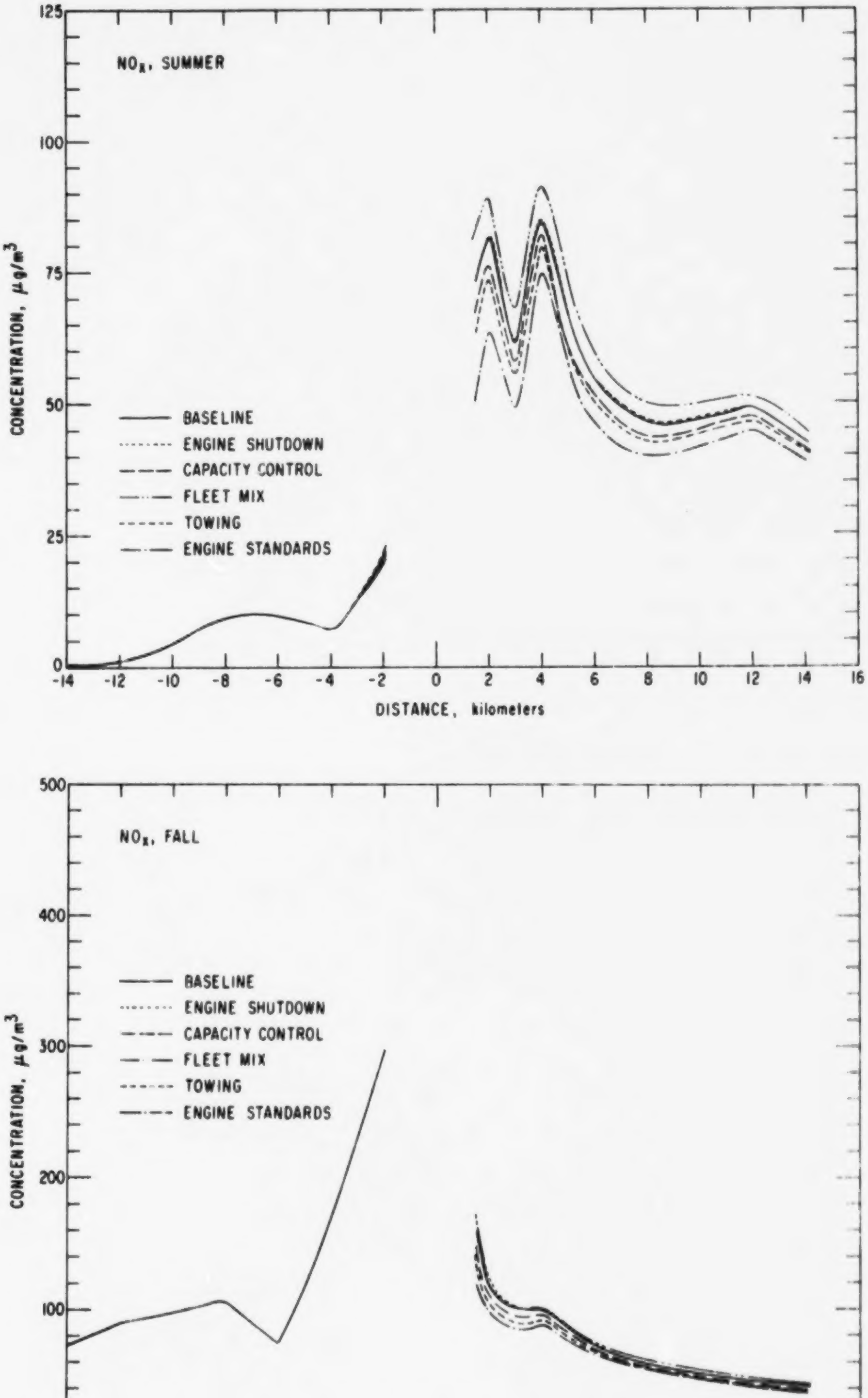


Fig. 26. Strategy Impact on Wind Line NO$_x$ Profiles

6.2.2 Worst Case Conditions

The same worst case conditions of poor atmospheric ventilation and high aircraft activity that were evaluated for their impact on airport air quality were also evaluated for their impact on regional air quality. Figures 27-29 show the regional isopleths under these conditions. Comparison of these figures to the fall conditions on Figs. 19-21 indicates the impact of these adverse conditions. Two things are immediately evident. First, the geometry of the isopleths assumes a more definitive "plume" shape following the general wind direction. The lobes and distortions in the isopleth lines under normal conditions disappear as the low lid height and light winds promote a uniform mixing of pollutants under the lid and inhibit any lateral dissipation of the concentration. This is the same type of behavior as can be observed for a single point source emitting under the same conditions.

The second observation is that the high pollutant concentration lines begin upwind of the airport. The City of Atlanta plays a significant role in the generation of the calculated concentrations and the airport, with its increased emission rate, compounds the situation.

As in the airport impact analysis, nowhere in the region is the National Ambient Air Quality Standard for CO being violated, even under these worst case conditions. There are numerous locations up- and downwind of the airport where the hydrocarbon limit is being exceeded. The 200 $\mu g/m^3$ isopleth appears to originate just downwind of the Atlanta CBD and extends far south of the airport. The airport makes a significant HC impact in the areas just downwind with the effect dropping off rapidly in the lateral direction. For NO_x, the high concentration zone as measured by the 300- and 150-$\mu g/m^3$ isopleths also begins just south of the Atlanta CBD and extends far to the south.

Table 26 shows the effect of each strategy on the concentrations downwind of the ALP. The worst case conditions have their largest relative impact on the region far downwind; the increase is almost a factor of 10. This area has very low concentrations under normal conditions due to its relatively undeveloped condition. The strategies have diminishing impacts in these areas. As before, the towing control option provides maximum air quality improvement for CO and HC and the engine emission standards for NO_x. The fleet mix change results in an increase in NO_x concentrations and the engine shutdown and capacity control strategies provide only small changes.

ALL CONCENTRATIONS IN μG/M³, 1-HOUR AVERAGE

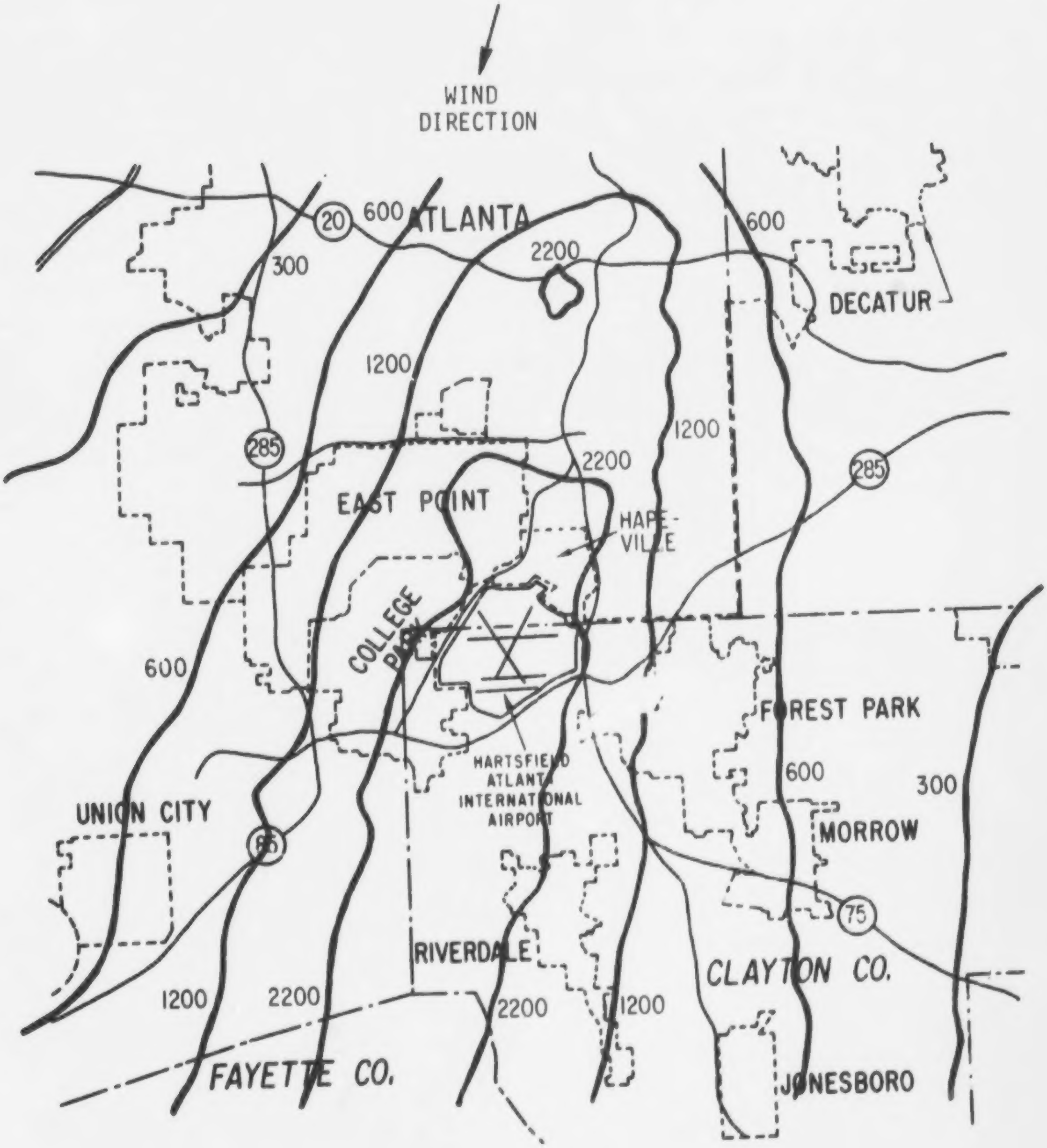

WIND DIRECTION
ATLANTA
20
600
300
2200
600
DECATUR
1200
285
1200
2200
EAST POINT
HAPE-VILLE
285
COLLEGE PARK
600
FOREST PARK
HARTSFIELD ATLANTA INTERNATIONAL AIRPORT
600
300
UNION CITY
85
MORROW
75
RIVERDALE
CLAYTON CO.
1200
2200
2200
1200
FAYETTE CO.
JONESBORO

Fig. 27. Regional CO Concentrations for Worst Case Situation

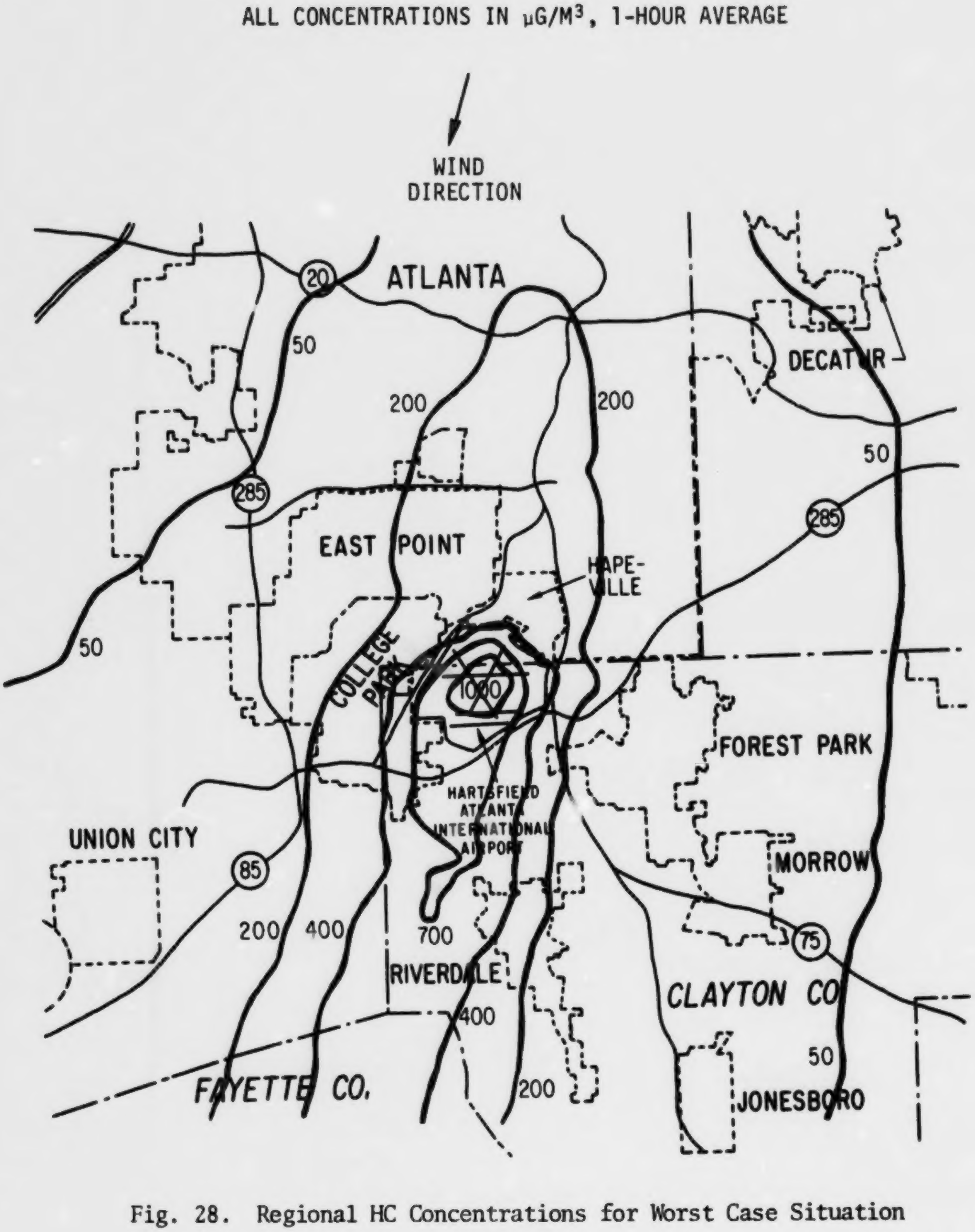

ALL CONCENTRATIONS IN μG/M³, 1-HOUR AVERAGE
WIND DIRECTION
20
ATLANTA
50
DECATUR
200
200
50
285
285
EAST POINT
HAPE-VILLE
50
COLLEGE PARK
1000
FOREST PARK
HARTSFIELD ATLANTA INTERNATIONAL AIRPORT
UNION CITY
MORROW
85
200
400
700
75
RIVERDALE
CLAYTON CO
400
50
FAYETTE CO.
200
JONESBORO

Fig. 28. Regional HC Concentrations for Worst Case Situation

ALL CONCENTRATIONS IN $\mu G/M^3$, [illegible]-HOUR AVERAGE

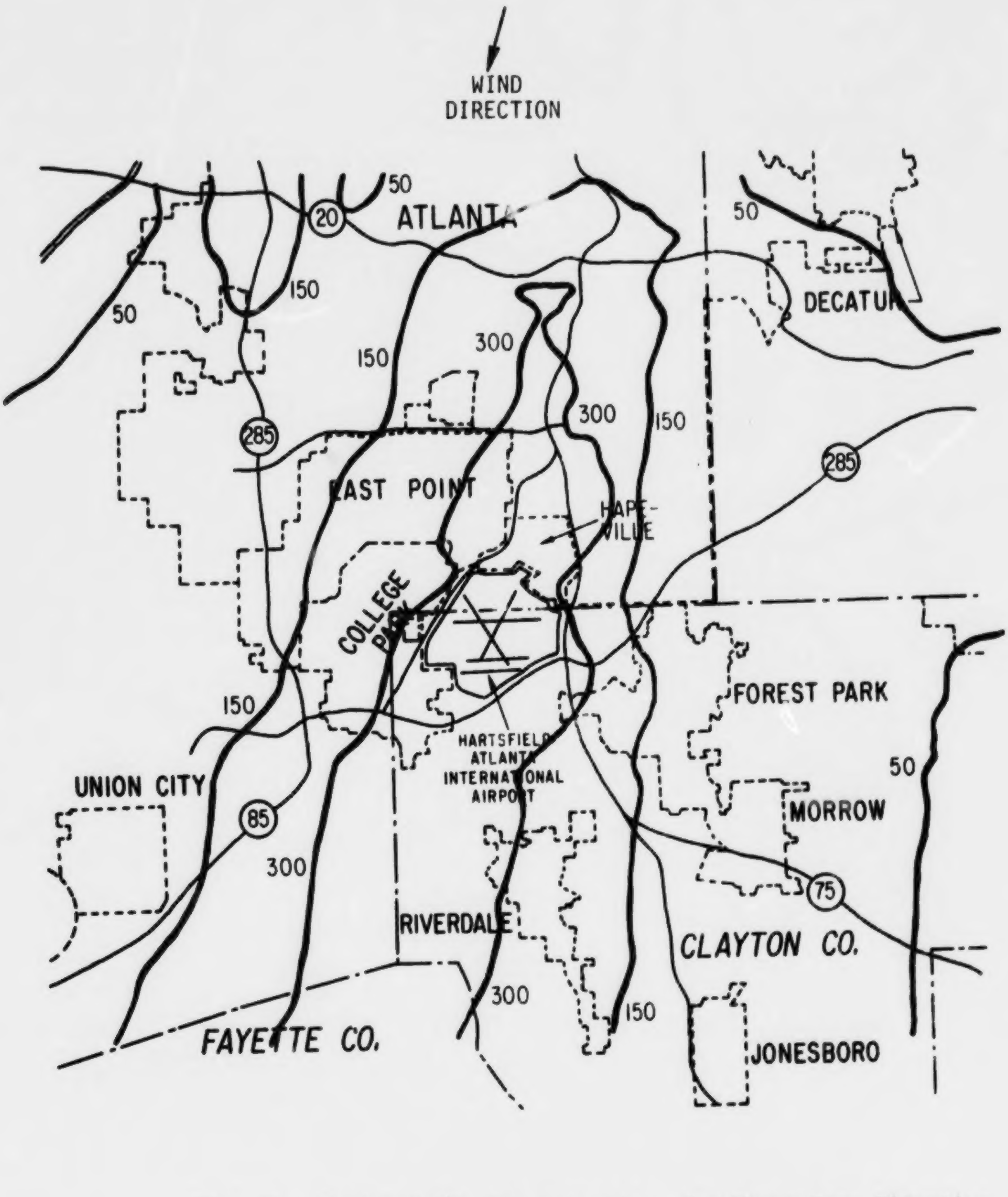

WIND DIRECTION
50
ATLANTA
20
50
150
150
300
300
150
50
DECATUR
285
285
EAST POINT
HAPEVILLE
COLLEGE PARK
150
HARTSFIELD ATLANTA INTERNATIONAL AIRPORT
FOREST PARK
50
UNION CITY
85
MORROW
300
75
RIVERDALE
CLAYTON CO.
300
150
FAYETTE CO.
JONESBORO

Fig. 29. Regional NO_x Concentrations for Worst Case Situation

TABLE 26. Regional CO, HC, NO_x Concentrations for Worst Case Conditions[a]

Downwind Distance from ALP (km)		Baseline	% Change Over Normal Conditions	Engine Shutdown	% Change	Towing	% Change	Capacity Control (70% LF)	% Change	Fleet Mix	% Change	Emission Standards	% Change
2	CO	3485	308	3407	-2.2	2603	-25.3	3325	-4.6	3120	-10.5	2938	-15.7
	HC	843	211	808	-4.2	474	-43.8	772	-8.4	575	-31.8	516	-38.8
	NO_x	486	312	486	0.0	442	-9.1	469	-3.5	489	+0.6	446	-8.2
6	CO	3261	607	3192	-2.1	2537	-22.2	3128	-4.1	2941	-9.8	2794	-14.3
	HC	724	530	66	-3.9	434	-40.1	668	-7.7	523	-27.8	472	-34.8
	NO_x	486	562	486	0.0	448	-7.8	469	-3.5	498	+2.5	441	-9.3
14	CO	2816	969	2775	-1.5	2386	-15.3	2737	-2.8	2615	-7.1	2521	-10.5
	HC	535	919	519	-3.0	364	-32.0	503	-6.0	417	-22.1	383	-28.4
	NO_x	437	951	437	0.0	415	-5.0	425	-2.7	456	+4.3	398	-8.9

[a] All concentrations in $\mu g/m^3$, 1-hr average.

6.2.3 Hydrocarbon Analysis

As indicated in previous discussions, comparison of the calculated hydrocarbon concentrations to the National Ambient Air Quality Standard requires a computation of a three-hour average for the hours of 6-9 AM. Since the AVAP Short-Term Model makes its computations on a one-hour time scale, the three-hour average is calculated from the results of each individual hour. The model does not store information from the previous hour's calculations and so does not account for any changes in concentration that might result from a change in emission characteristics or meteorology that occurred longer than an hour away in time. The lack of an algorithm to represent photochemical reactions involving hydrocarbons has already been discussed. The results of this analysis, therefore, must be viewed in the light of the model's limitations.

In making AVAP model runs for the hours 6-7, 7-8, and 8-9 AM, the diurnal distribution of emission activity is included for each hour. Since the air quality standard allows only one excess per year, the meteorological conditions chosen for this analysis were the same as the worst case conditions previously described. It is not unreasonable to assume that the light winds and low lid would persist for three consecutive hours. Also, the aircraft activity in these hours is fairly high (see Table 5) indicating that long queue formation is possible under adverse visibility conditions.

Figure 30 shows the three-hour average concentrations calculated for baseline conditions and the towing and engine emission standards control strategies. It is evident that upwind of the airport the standard is being violated. The airport adds substantial HC emissions and boosts the concentration even higher downwind. Note that the calculated concentrations resulting from airport sources only is still above the 160 $\mu g/m^3$ standard. The indication is that emissions from the airport alone could result in violation of the standard.

The two control strategies tested provide significant improvement although neither is capable of reducing the concentrations below the standard. Given the high HC levels being transported over the airport from other sources, this condition is not unexpected. The fleet mix strategy was not tested here because it resulted in increased NO_X concentrations.

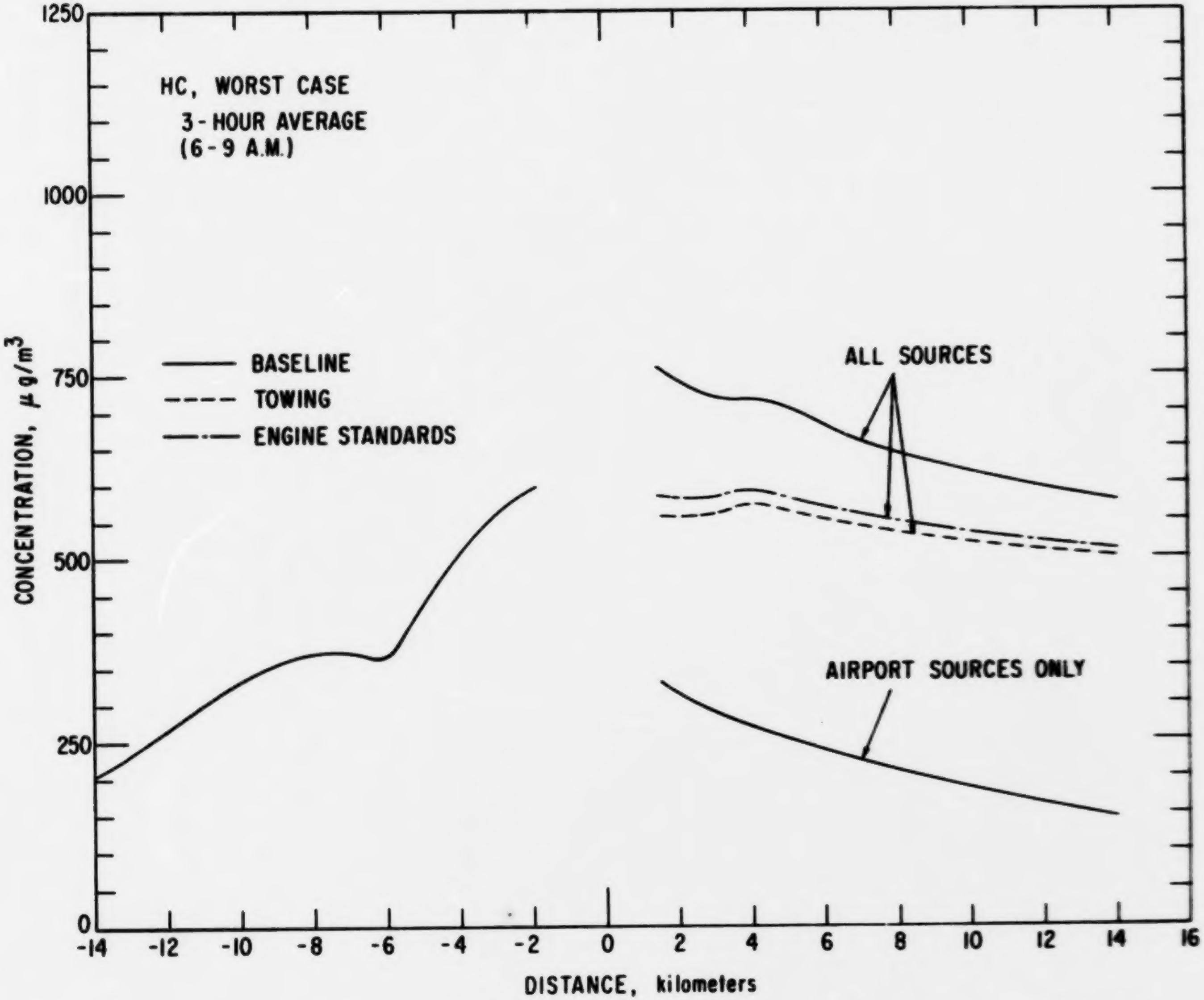


Fig. 30. Regional 3-Hour Hydrocarbon Concentrations Under Worst Case Conditions

6.2.4 Long-Term Air Quality

The long-term version of the AVAP model was used to compute annual average pollutant concentrations for the airport and vicinity. Because this computer package requires very long running times (in the vicinity of one hour), the receptor grid used for the calculation was made coarser and the number of receptors was reduced in order to achieve machine time savings. The fine grid on the airport site was removed and calculations were made only for the eight GEOMET monitor site locations and the Airport Location Point (see Fig. 3). The regional grid was enlarged to 4 x 4 km (as compared to 3 x 3 km previously) while covering basically the same area.

Figures 31-33 show the isopleths of calculated annual average concentrations. Tables 27-29 show the computed concentrations at nine regional receptors, the center one of which is in the approximate center of the airport (see Fig. 15 for location of receptors) and the extreme ones of which are on lines 4 km away. Also shown are the concentrations calculated at the eight GEOMET sites, the ALP, and the worst non-airport receptor.

From the tables it is evident that airport sources contribute only small amounts to the annual average concentrations at the receptors 4 km away; there is a maximum of 37.1 $\mu g/m^3$ of CO, 15.2 $\mu g/m^3$ of HC, and 7.6 $\mu g/m^3$ of NO_X contributed by the airport at these sites. In contrast, the environs contribute substantial amounts to the concentrations on the airport sites; for CO it is in the range of 230-380 $\mu g/m^3$, for HC 68-96 $\mu g/m^3$, and for NO_X 42-83 $\mu g/m^3$.

The environ contributions at receptor number 7 are significantly higher than at other sites primarily due to the influence of the long stretch of I-85 nearby. The hydrocarbon concentrations due to airport sources at sites 1 and 2 are high since these two locations are close to fuel farms and hence are exposed to large quantities of evaporative emissions. Receptors 7 and 8 lie under the approach and departure paths for runway 8/26 and hence experience the highest NO_X concentrations since aircraft NO_X emissions are highest in the approach and takeoff power settings. That similar high NO_X levels are not calculated at receptors 3 and 5, which are near the flight paths for the southern runways, may be a result of the fact that one runway is used for departures and the other for takeoffs. The separation distance provides added dispersion space and so may result in the lower values.

ALL CONCENTRATIONS IN μG/M³, ANNUAL AVERAGE

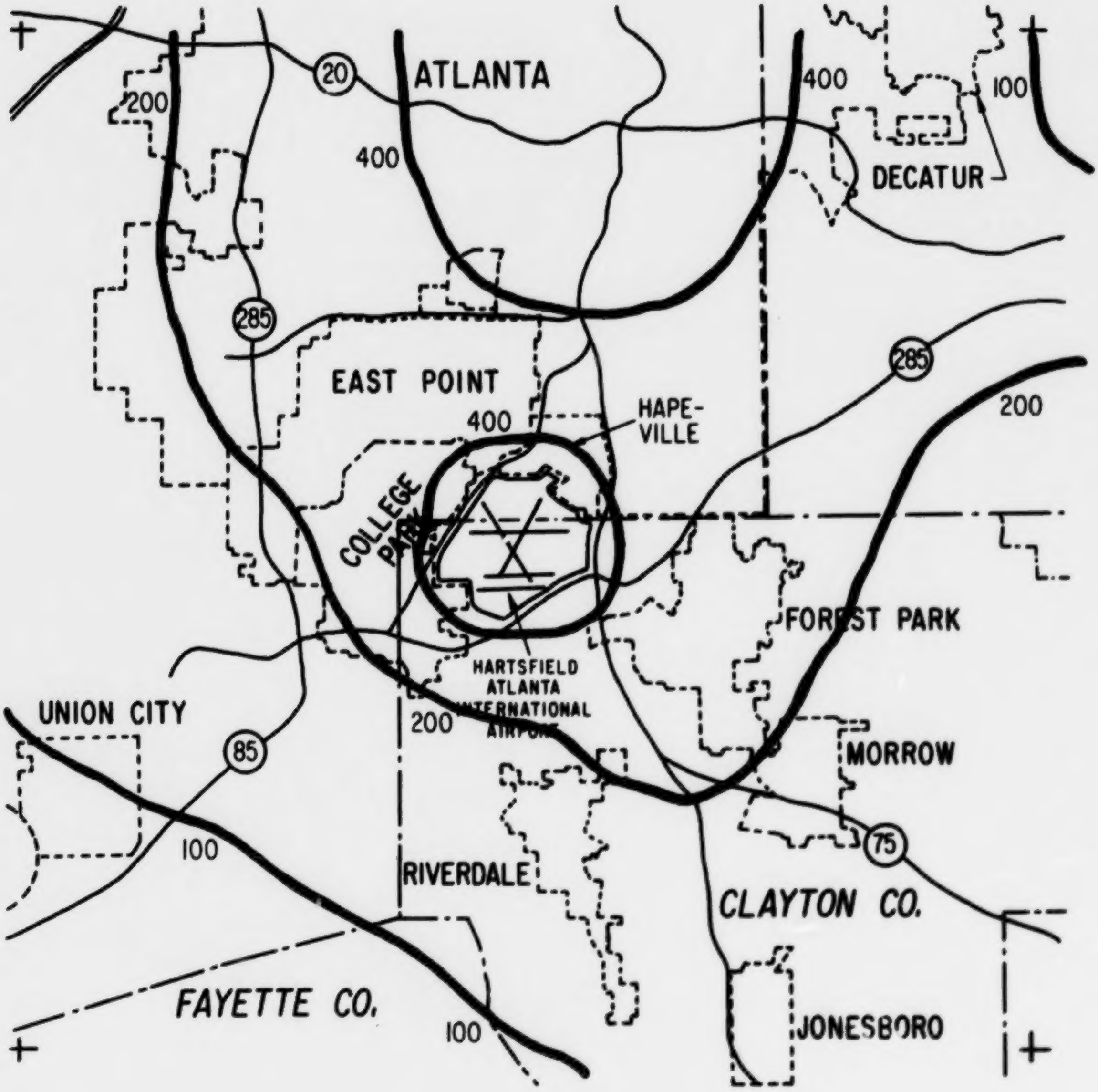

20
ATLANTA
400
200
400
100
DECATUR
285
EAST POINT
400
HAPE-
VILLE
285
200
COLLEGE
PARK
HARTSFIELD
ATLANTA
INTERNATIONAL
AIRPORT
FOREST PARK
UNION CITY
200
85
MORROW
100
75
RIVERDALE
CLAYTON CO.
FAYETTE CO.
100
JONESBORO

Fig. 31. Annual Average CO Concentrations Under Baseline Conditions

ALL CONCENTRATIONS IN $\mu G/M^3$, ANNUAL AVERAGE

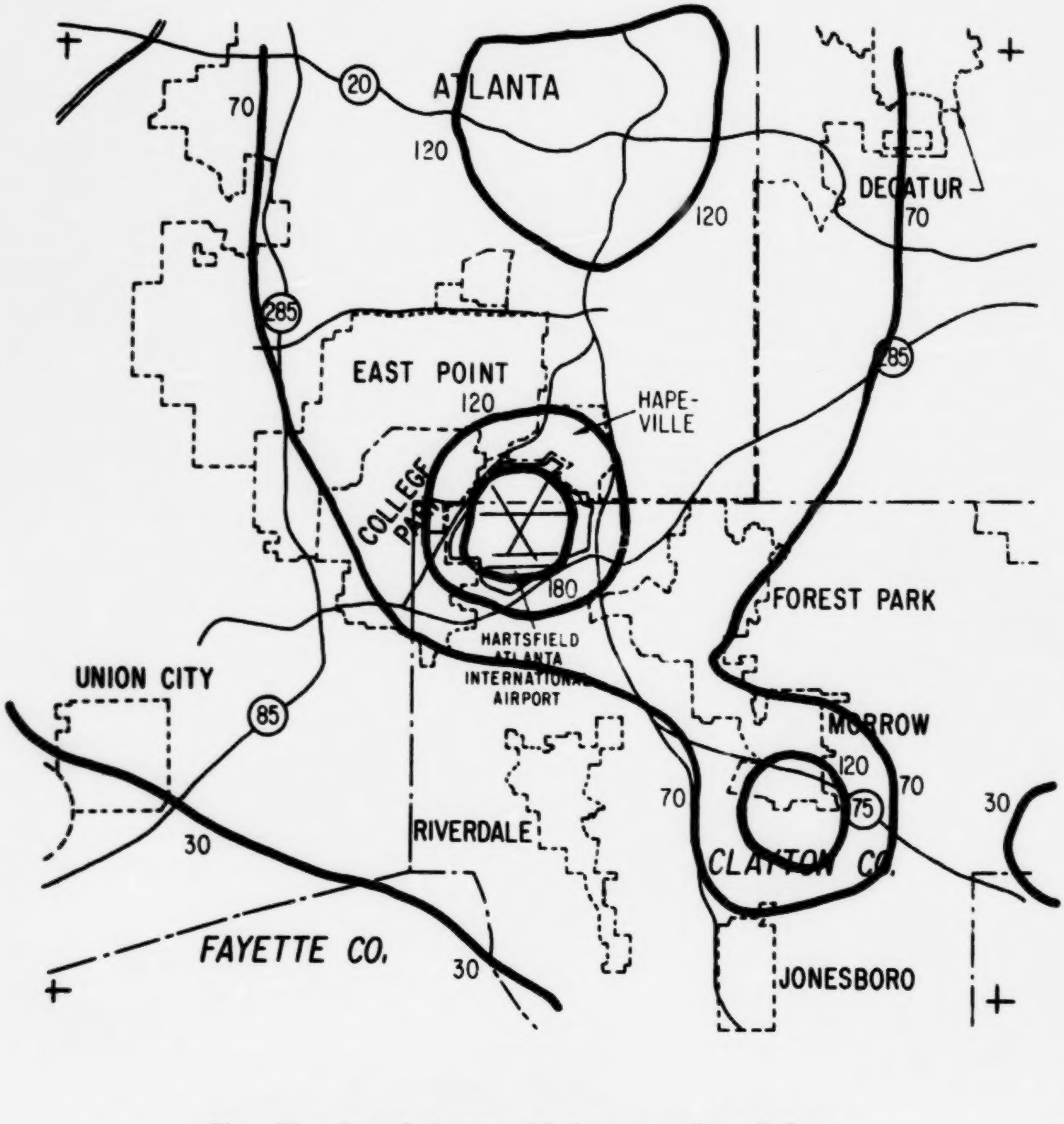

ATLANTA
20
70
120
120
DECATUR
70
285
EAST POINT
120
HAPE-VILLE
COLLEGE PARK
180
HARTSFIELD ATLANTA INTERNATIONAL AIRPORT
285
FOREST PARK
UNION CITY
85
MORROW
120
70
70
75
30
30
RIVERDALE
CLAYTON CO.
FAYETTE CO.
30
JONESBORO

Fig. 32. Annual Average HC Concentrations Under Baseline Conditions

ALL CONCENTRATIONS IN $\mu G/M^3$, ANNUAL AVERAGE

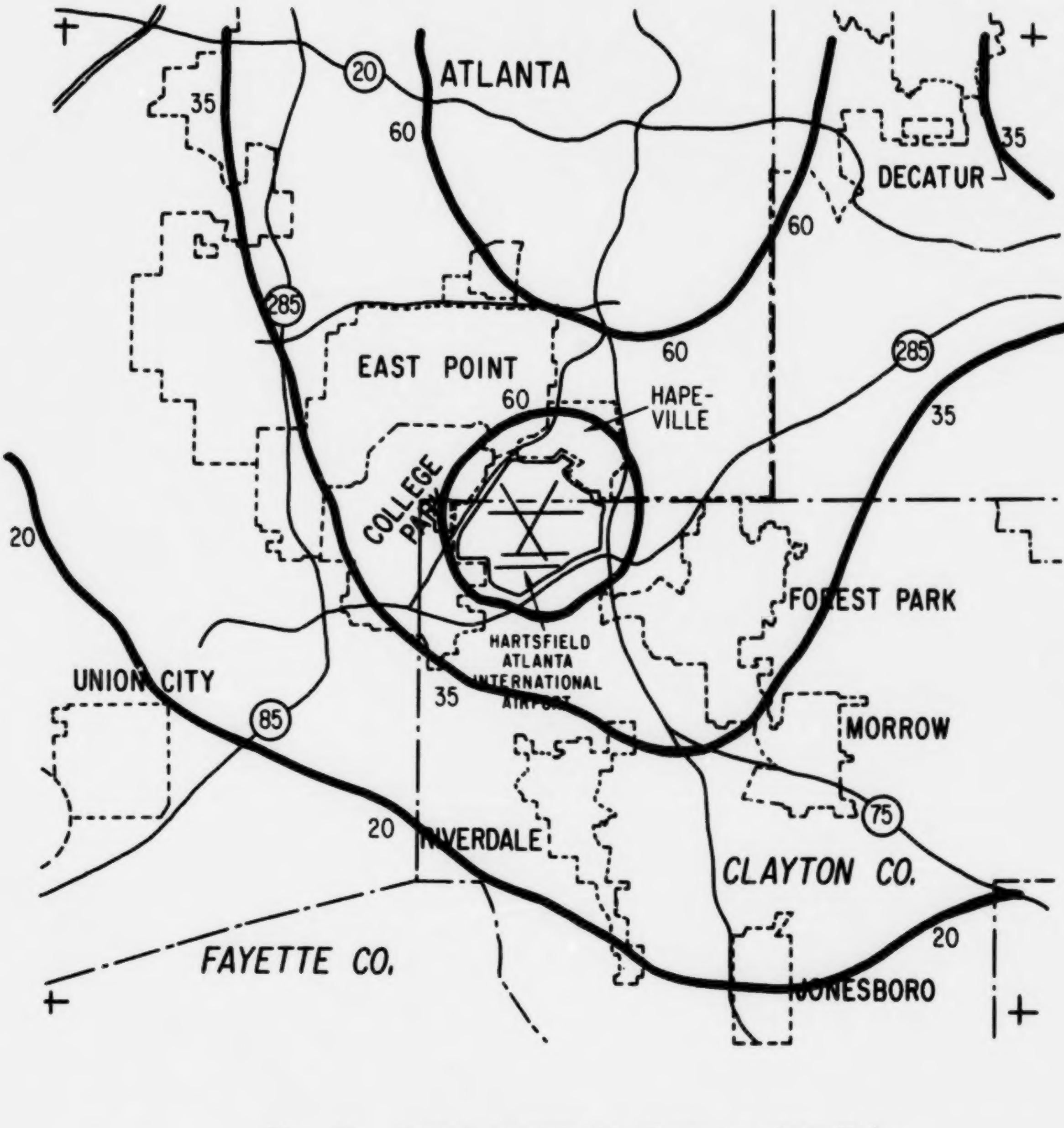

ATLANTA
DECATUR
EAST POINT
HAPE-VILLE
COLLEGE PARK
FOREST PARK
HARTSFIELD ATLANTA INTERNATIONAL AIRPORT
UNION CITY
MORROW
RIVERDALE
CLAYTON CO.
FAYETTE CO.
JONESBORO
20
285
85
75
35
60
60
60
60
60
35
35
35
35
20
20
20

Fig. 33. Annual Average NO_x Concentrations Under Baseline Conditions

TABLE 27. Annual Average CO Concentrations for Baseline Conditions

All concentrations in μg/m³

		UTM X-Coordinate[a] (km)			
		734.5	738.5	742.5	
UTM Y-Coordinate[a] (km)	3729.5/	13.0	28.3	18.1	
		262.9	332.5	313.9	
		275.9	360.8	332.0	
	3725.5/	24.4	372.2	37.1	
		215.8	255.5	265.4	
		240.2	627.7	302.5	
	3721.5/	10.3	12.1	20.7	Airport
		160.6	194.0	223.8	Environs
		170.9	206.1	244.5	Total

Receptor	Contribution to Concentration (μg/m³) Airport	Environs	Total
GEOMET #1	429.0	256.1	685.1
#2	252.2	245.6	497.8
#3	91.6	255.5	347.1
#4	55.9	232.3	288.2
#5	69.5	247.1	316.6
#6	158.5	247.5	406.0
#7	189.0	381.1	570.1
#8	249.7	281.9	531.6
Airport Location Point	287.9	272.1	560.0
Worst Non-Airport Receptor (738.5, 3737.5)	4.7	619.0	623.7

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[a] Universal Transverse Mercator coordinate system, zone 16.

TABLE 28. Annual Average HC Concentrations for Baseline Conditions

All Concentrations in μg/m³

		UTM X-Coordinate[a] (km)			
		734.5	738.5	742.5	
UTM Y-Coordinate[a] (km)	3729.5/	5.6	12.1	7.8	
		81.9	101.1	96.4	
		87.5	113.2	104.2	
	3725.5/	10.6	140.4	15.2	
		67.1	80.1	82.3	
		77.7	220.5	97.5	
	3721.5	4.5	5.3	8.9	Airport
		50.1	57.0	65.1	Environs
		54.6	62.3	74.0	Total

	Contribution to Concentrations (μg/m³)		
Receptor	Airport	Environs	Total
GEOMET #1	193.9	80.8	274.7
#2	115.5	74.0	189.5
#3	38.2	73.6	111.8
#4	22.8	68.1	90.9
#5	27.7	71.5	99.2
#6	77.4	76.7	154.1
#7	79.2	96.2	175.4
#8	95.7	87.0	182.7
Airport Location Point	145.4	85.4	230.8
Worst Non-Airport Receptor (746.5, 3717.5)	3.4	144.1	147.5

[a] Universal Transverse Mercator coordinate system, zone 16.

TABLE 29. Annual Average NO_x Concentrations for Baseline Conditions

All Concentrations in $\mu g/m^3$

		UTM X-Coordinate[a] (km)			
		734.5	738.5	742.5	
UTM Y-Coordinate[a] (km)	3729.5/	2.1 40.7 42.8	3.3 53.8 57.1	2.7 52.8 55.5	
	3725.5/	4.4 35.2 39.6	42.2 45.2 87.4	7.6 46.8 54.4	
	3721.5/	2.1 27.3 29.4	2.2 33.6 35.8	4.1 36.5 40.6	Airport Environs Total

Receptor	Contribution to Concentrations ($\mu g/m^3$) Airport	Environs	Total
GEOMET #1	44.2	45.4	89.6
#2	24.7	43.0	67.7
#3	26.6	47.9	74.5
#4	15.0	42.0	57.0
#5	32.4	47.1	79.5
#6	20.9	43.8	64.7
#7	46.2	83.1	129.3
#8	115.6	51.2	166.8
Airport Location Point	43.4	48.0	91.4
Worst Non-Airport Receptor (738.5, 3737.5)	0.8	90.8	91.6

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[a] Universal Transverse Mercator coordinate system, zone 16.

The combination of airport- and environ-contributed concentrations results in a violation of the National Ambient Air Quality Standard for NO_2 (100 μg/m³ annual average) at two airport locations (7 and 8) and the calculated air quality being within 20% of the standard at three other locations (1, 5, and the ALP). The region in excess of the standard is confined principally to the airport at the ends of the runway. It must be emphasized that the problem is a combination of airport and environ sources. At receptors 7 and 8 the airport is contributing about one-third of the calculated NO_X concentrations.

It is interesting to note that for hydrocarbons, six of the receptors are showing annual average concentrations that are above or very close to the three-hour standard of 160 μg/m³. While this does not mean that the standard will be violated during the 6-9 AM time period, it does indicate that hydrocarbons will be a perennial problem at the airport. As with the other analyses, CO concentrations are very low.

The engine emission standards strategy was also run with the long-term model as this was the only control option that addressed the NO_X problem. Figure 34 shows the annual average NO_X concentration isopleths and Table 30 shows the impact of the strategy at the receptor locations. It is evident that there is only a small impact on the receptors 4 km away from the airport (maximum of 3.8% for CO, 7.3% for HC, and 5.0% for NO_X) but significant impacts on the airport site. The strategy shrinks the area in excess of the 100 μg/m³ NO_2 standard and also provides significant reductions at the sites that were close to violation (1, 5, and the ALP). For hydrocarbons it reduces all points below the 160 μg/m³ level. This strategy is, therefore, effective for long-term NO_X and HC control.

ALL CONCENTRATIONS IN μG/M³, ANNUAL AVERAGE

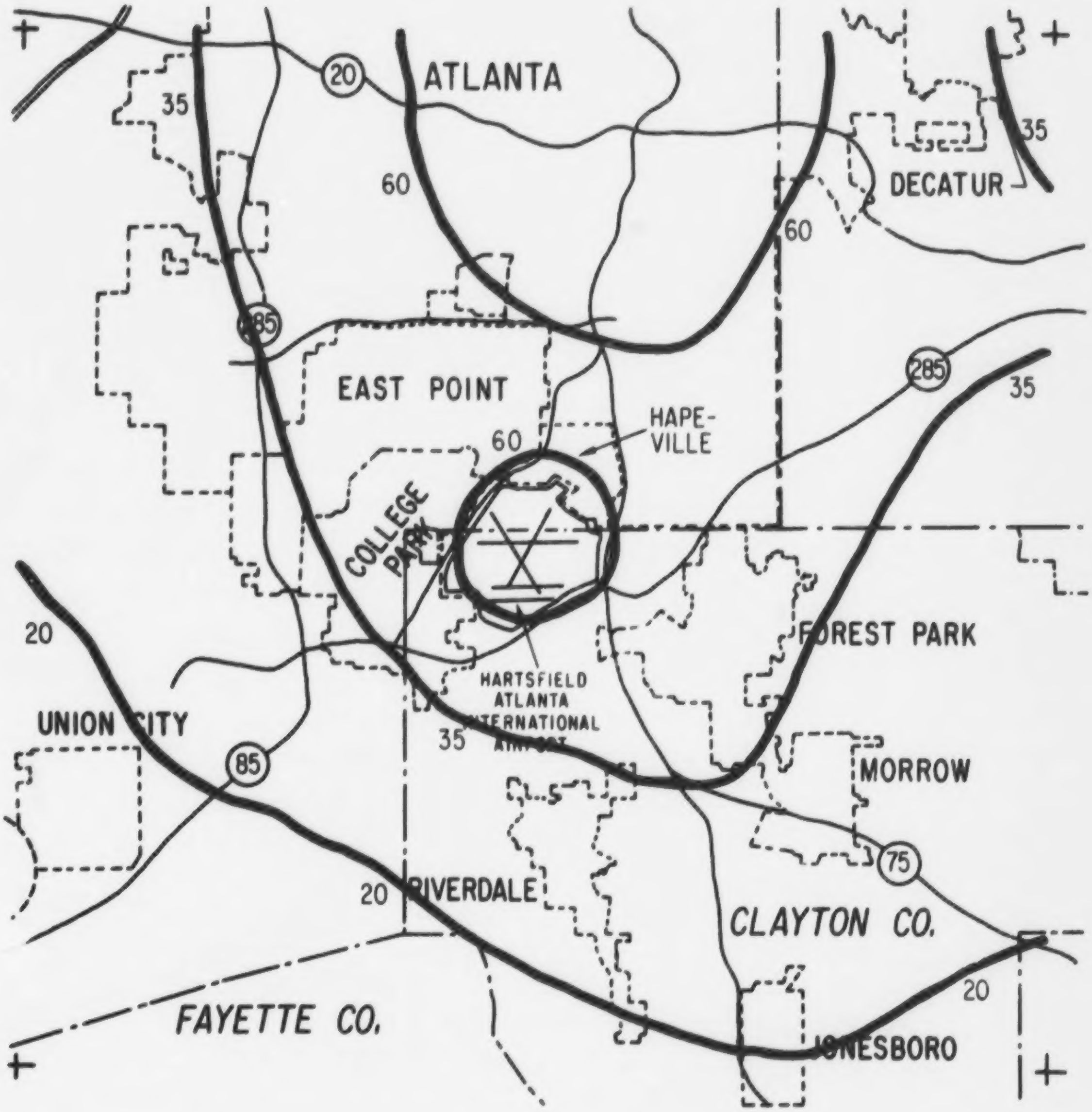
ATLANTA
20
35
60
60
DECATUR
35
285
EAST POINT
60
HAPE-VILLE
285
35
COLLEGE PARK
20
FOREST PARK
HARTSFIELD ATLANTA INTERNATIONAL AIRPORT
UNION CITY
85
35
MORROW
75
20
RIVERDALE
CLAYTON CO.
20
FAYETTE CO.
JONESBORO

Fig. 34. Annual Average NO_x Concentrations for Engine Emission Standards Strategy

TABLE 30. Effect of Engine Emission Standards on Annual Average Concentrations[a]

Receptor		CO			HC			NO_X		
UTM-X[b] (km)	UTM-Y[b] (km)	Baseline	Engine Standards	% Change	Baseline	Engine Standards	% Change	Baseline	Engine Standards	% Change
734.5	3721.5	170.9	167.8	-1.8	54.6	52.6	-3.7	29.4	28.6	-2.7
	3725.5	240.2	233.0	-3.0	77.7	73.0	-6.0	39.6	38.0	-4.0
	3729.5	275.9	272.3	-1.3	87.5	85.1	-2.7	42.8	42.1	-1.6
738.5	3721.5	206.1	202.4	-1.8	62.3	59.8	-4.0	35.8	35.1	-2.0
	3725.5	627.7	457.3	-27.1	220.5	143.2	-35.1	87.4	71.1	-18.6
	3729.5	360.8	353.1	-2.1	113.2	108.2	-4.4	57.1	56.1	-1.8
742.5	3721.5	244.5	237.4	-2.9	74.0	69.7	-5.8	40.6	39.1	-3.7
	3725.5	302.5	290.9	-3.8	97.5	90.4	-7.3	54.4	51.7	-5.0
	3729.5	332.0	326.5	-1.7	104.2	100.7	-3.4	55.5	54.6	-1.6
GEOMET Site #1		685.1	468.0	-31.7	274.7	154.1	-43.9	89.6	72.3	-19.3
#2		497.8	369.4	-25.8	189.5	116.4	-38.6	67.7	58.5	-13.6
#3		347.1	312.4	-10.0	111.8	92.0	-17.7	74.5	64.2	-13.8
#4		288.2	264.4	-8.3	90.9	77.5	-14.7	57.0	51.6	-9.5
#5		316.6	287.9	-9.1	99.2	83.1	-16.2	79.5	65.0	-18.2
#6		406.0	338.1	-16.7	154.1	114.1	-26.0	64.7	57.3	-11.4
#7		570.1	495.1	-13.2	175.4	131.6	-25.0	129.3	109.2	-15.5
#8		531.6	422.2	-20.6	182.7	121.7	-33.4	166.8	117.9	-29.3
Airport Location Point		560.0	438.9	-21.6	230.8	153.6	-33.4	91.4	74.6	-18.4

[a] All Concentrations in $\mu g/m^3$.

[b] Universal Transverse Mercator coordinate system, zone 16.

7.0 THE IMPACT OF GROWTH

This section will deal with the evaluation of the impacts of growth and development in the Atlanta area on airport and airport-influenced regional air quality.

7.1 DEVELOPMENT SCENARIO

Change in the Atlanta region with time will alter the quantity and distribution of pollutant emissions. Because maintenance of satisfactory air quality, once achieved, is a requirement for air quality control programs, it is desirable that proposed aircraft control strategies be evaluated against projected, as well as current, regional conditions. The airport model is ideally suited for calculating the net effects of the interplay of changes to the various sources in the region and evaluating the probable effectiveness of aircraft control strategies. Information about possible levels of growth and development patterns in the region have been combined with projections of passenger enplanements at the airport to adjust the source inventory to values appropriate for 1980 and 1990. Adjustments only in the magnitudes of the emissions were made, with no changes in the geometric definition of any source.

Projections of regional growth are dependent on the assumptions used and the purposes to be served in making the projections. Regional growth estimates used in this study are based primarily on information from three sources. The Atlanta Regional Commission (ARC) supplied information[20] regarding the distribution and growth of population and economic activity throughout the region. Growth of industrial point sources has been based on the projection[21] of economic activity in the Atlanta region prepared for the USEPA by the Bureau of Economic Analysis (BEA), U.S. Department of Commerce. Studies performed for the Atlanta Airport Authority furnished information about the projected levels of air traffic at the airport.[13]

Information received from ARC is strongly conditioned by the assumptions behind it and its intended purpose. As part of the Commission's program to develop a plan for the region, several alternative development outcomes, based on differing transportation scenarios, have been calculated. The same projected overall regional population growth is distributed across the region in alternative patterns determined by transportation-related attributes, such as accessibility. These alternatives are being used, in part, to stimulate general public awareness and discussion of the possibilities for regional development and to hopefully lead to concurrence on a set of policies to enhance the prospects of attaining the desired development outcomes. The changes with time in the environ area sources in the airport model are based on the results of ARC calculations for one of these development scenarios, the "null" alternative that considered "the implications of a limited future transportation system for the region" consisting of no new highways and only the already adopted plans for the MARTA rail rapid transit system. Examination of these results shows a development pattern that continues an expansionary trend to 1980, after which poor accessibility at the fringes of the developed area forces a recentralization of further growth.

Of direct use in the adjustment of the source inventory are tabulations of census tract populations, occupied residences, proportion of multi-family residences, and land areas occupied for commercial and for industrial uses in 1970, 1980, and 1990. The jurisdictional boundaries of the towns of over 2500 population chosen as the basis of the current source inventory are, unfortunately, often not coincident with census tract boundaries. Growth of towns, therefore, has been calculated in the following way: The average growth rates for the important tabulated values for a set of census tracts roughly overlapping a town have been applied to the 1970 base values for the town itself. The boundaries of the towns have been assumed not to change. Several pollutant generating activities are calculated to vary at the same rate as the population, among which are waste incineration, gasoline consumption, solvent use, and dry cleaning. Space heating emissions from residential, commercial, and industrial units are increased by the separate growth rates tabulated for each. The total emissions for each town and the residual county-wide emissions are then transformed onto the regional grid system described in Section 6.1.

Automotive traffic emissions projections are based on population changes. Traffic on local streets has been assumed to vary with the population in the same area; this traffic appears as area sources in the regional grid. The traffic on freeways, on the other hand, probably is more strongly dependent on the growth of overall regional population. The total vehicle miles on the freeway line sources near the airport have been, correspondingly, increased in proportion to total regional growth. Traffic emission rates appropriate to the vehicle age distribution and engine emission control standards of 1980 and 1990 have been used.

Point sources beyond the airport boundaries are derived from the inventory assembled by the Georgia Department of Natural Resources in the National Emissions Data System (NEDS) format. An element of the information for each source is the Standard Industrial Classification (SIC) code number for the primary economic activity of the facility. The BEA projection of economic activity in the Atlanta area provides growth rates for a number of industries in categories compatible with the SIC coding system. These projections of growth to 1980 and 1990 have been applied directly to the corresponding industrial point sources in our inventory, and all growth in emissions has been assumed to occur in place, without the creation of any new point sources. Several of the types of "point" sources that might be rather diffuse, such as quarrying operations or clustering of stacks associated with large governmental installations, have been entered into our inventory as area sources on the basic regional source grid. The growth of these sources, nevertheless, follows the BEA projections for the appropriate SIC classes.

Projections of numbers of passengers that will be using the Atlanta airport have been used to alter the magnitudes of sources directly related to passenger levels, foremost among which are access traffic and use of parking facilities. No major construction has been assumed, so that space heating emissions from airport buildings remain unchanged.

Although the amount of aircraft activity will necessarily increase to service the increased passenger levels, recognition has been made of the fact that the aircraft in commercial use in 1980 and 1990 will likely be different from the current fleet. In particular, it is anticipated that the fleet mix will change toward domination by medium range and jumbo jet aircraft, with a phasing out by 1980 of most of the older long-range aircraft (e.g. DC-8, CV-880, etc.). This change in fleet mix is incorporated into the 1980 and 1990 inventories of aircraft activity as the baseline condition. The 1990 baseline conditions also include aircraft emission rates that reflect the engine standards that will be universal by that time.

7.2 STRATEGY IMPACT ON REGIONAL EMISSIONS

Changes in pollutant emissions with time result from changing numbers of sources and from changes in source emission rates due, for example, to compliance with emission control standards. Changes in the emissions of three pollutants in the Atlanta region through 1990 are displayed in Fig. 35. Total emissions from the inventory used for dispersion model calculations are divided into two major categories: emissions directly attributable to airport activity and emissions from all other sources in the study area, called the environs. In general, the airport becomes a larger factor in the regional emissions with the passage of time.

Relative distribution of baseline emissions among source subcategories listed in Table 31 reveals the causes of the overall behavior shown in Fig. 35. Specific inventory elements in each subcategory are detailed in Table 32. Changes in the environ emissions are strongly conditioned by the dramatic decline in automotive emissions accompanying the evolution of the vehicle model year mix to uniform compliance with more stringent emission standards. The effect is most pronounced for carbon monoxide emissions which are overwhelmingly dominated by automotive emissions. Evaporation of hydrocarbons, primarily associated with gasoline marketing and inventoried as part of the stationary area sources, nearly counterbalances the improvement in hydrocarbon emissions from motor vehicles. Relative improvement in emissions of nitrogen oxides from motor vehicles is somewhat less than for carbon monoxide and hydrocarbons and is exceeded by the increase in uncontrolled nitrogen oxide emissions from the large point sources in the region. The result is a gradual increase in environ nitrogen oxide emissions throughout the time period. The total number of vehicle miles traveled annually in the region is continuously increasing, but this factor has been more than offset by the improved vehicle emission rates. Toward the end of the period, however, the full impact of the control of emissions will have been attained, after which vehicle miles traveled would again become the dominant factor.

The effect of motor vehicle emission control standards appears among airport related sources only in the ground mobile source subcategory. Because passenger enplanements are anticipated to grow at a faster rate than overall regional population, the increase in access traffic at the airport

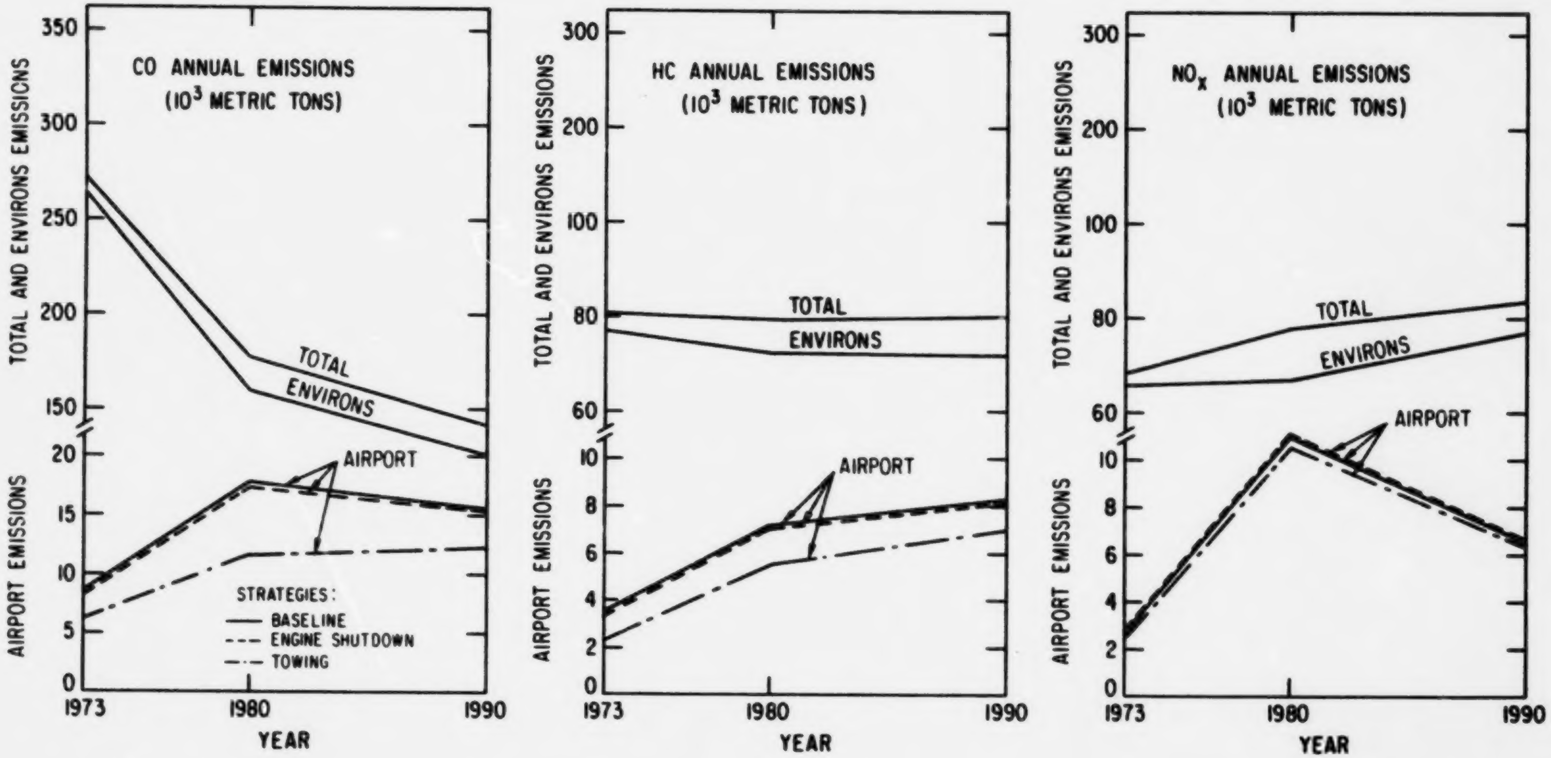

Fig. 35. Pollutant Emissions through 1990

TABLE 31. Percentages of the Regional Pollutant Emissions Attributable to the Various Types of Sources Inventoried for 1973, 1980, and 1990

Source Type	CO			HC			NO_x		
	1973	1980	1990	1973	1980	1990	1973	1980	1990
Environ Points	4.1	13.0	23.7	2.0	2.9	4.4	38.6	45.7	64.9
Environ Stationary Areas	4.6	9.6	12.6	57.2	69.6	72.8	6.2	7.0	6.4
Environ Mobile Areas	85.6	65.8	51.5	35.4	18.0	12.1	48.1	31.1	19.1
Environ Roadway Lines	2.5	1.6	1.2	1.1	.5	.4	3.2	2.1	1.7
Environ Total	96.8	90.0	89.0	95.7	91.0	89.7	96.1	85.9	92.1
Airport Facilities	.05	.13	.09	.8	3.1	4.0	.5	.7	.4
Airport Ground Mobile	.7	.7	.6	.26	.18	.14	.3	.3	.3
Aircraft	2.4	9.2	10.3	3.2	5.7	6.2	3.1	13.1	7.2
Airport Total	3.2	10.0	11.0	4.3	9.0	10.3	3.9	14.1	7.9
Total Regional Emissions (10^3 metric tons/year)	272.6	176.8	141.6	80.5	79.4	80.1	68.3	78.0	83.6

is steep enough to lessen the beneficial impact of the emission standards. For the majority of the airport sources, however, no emission controls become effective in the 1973-1980 time span. Change in the aircraft fleet mix to one dominated by jumbo and medium range jets does not prevent substantial increases in aircraft pollutant emissions by 1980. With emissions from environ sources maintained at nearly steady levels or even declining, these increases in aircraft emissions are translated directly into increased importance for aircraft among sources in the region. Airport facilities are not significantly large pollutant emitters, with the exception of fuel tank farms that become increasingly important sources of hydrocarbons. Between 1973 and 1980 the portion of the regional emissions accounted for by the airport increases by a factor greater than 2.

TABLE 32. Definitions of Source Types in Terms of Specific Inventory Elements

Source Type	Sources Included
Environ Points	Large point sources included in Georgia Department of Natural Resources inventory.
Environ Stationary Areas	Space heating for residential, commercial, and small industrial units; hydrocarbon evaporation from gasoline handling, dry cleaning, and solvent use; waste incineration; and clusterings of sources in the Georgia DNR inventory.
Environ Mobile Areas	Traffic on local streets and on freeways more than about 3 km from the airport.
Environ Roadway Lines	Traffic on freeways and major arterials near the airport.
Airport Facilities	Space heating of airport buildings; aircraft maintenance and repair; and fuel storage in tank farms at the airport.
Airport Ground Mobile	Access traffic to airport facilities and parking for airport traffic.
Aircraft	Aircraft and directly related equipment including ground service vehicles and ramp area refueling facilities.

Between 1980 and 1990, imposition of controls on the emissions of aircraft engines arrests the growth of airport emissions. New aircraft engine standards have effect not only on the aircraft emissions, but also on emissions from airport facilities through reduced emissions from aircraft maintenance and testing activities. For the baseline case, an absolute decline in carbon monoxide and nitrogen oxide emissions between 1980 and 1990 is the result. The increase in emission of hydrocarbons at the airport between 1980 and 1990 is in large part due to losses associated with refueling operations in the ramp area and evaporation from large storage tanks. In spite of the beneficial effects of the aircraft engine standards, the airport emissions will be a slightly larger portion of the regional totals for carbon monoxide and hydrocarbons in 1990 than in 1980, exceeding 10% of the regional emissions for both pollutants. Nitrogen oxide emissions at the airport, however, should be reduced both absolutely and in relation to other regional sources in the decade of the 80s.

Also shown in Fig. 35 are the effects of engine shutdown and aircraft towing strategies for reducing aircraft emissions. The engine shutdown strategy has been assumed to be applied in the same manner as during the test period of December 1973. It is effective only for inbound taxi operations and is participated in only by B-727 and DC-10 aircraft among those operating in 1980 and 1990. Engine shutdown produces a small decrease in airport emissions of carbon monoxide and hydrocarbons and a negligible increase in nitrogen oxides. Aircraft towing produces a much larger decrease in emissions than does engine shutdown, although it is only about 5% in airport nitrogen oxide emissions. The introduction of new aircraft engine standards by 1990 makes the towing strategy slightly less effective by bringing aircraft taxi emission rates and towing vehicle emission rates closer together. It should be noted from Fig. 35 that aircraft towing is not sufficient to prevent 1980 airport emissions from being larger than the 1973 baseline. The airport will assume a larger role in regional air quality by 1980 even if aircraft towing were to be used.

7.3 STRATEGY IMPACT ON AIR QUALITY

The concentrations of pollutants at several airport and regional locations have been calculated for the two sets of meteorological conditions used for the studies based on the 1973 source inventory. From these results it is possible to describe representative trends in air quality levels that would accompany the development scenario chosen.

7.3.1 Airport Air Quality

Two of the airport activity locations that were shown to be most sensitive to aircraft operational control strategies in Tables 20-22 are the aircraft ramp area at the terminal and the central fire station along taxiway C. The changes in pollutant concentrations calculated to occur at these two sites through 1990 are displayed in Figs. 36 and 37.

In the aircraft ramp area the dichotomy of wind directions between the typical summer and fall meteorological sets comes to be associated over time with distinctly different levels of pollutant concentration. In 1973 the baseline carbon monoxide and nitrogen oxide concentrations in the ramp area are roughly the same in summer and fall, while the summer HC concentration is about twice that occurring in fall. The sources that are important at the ramp area are different in the two cases, however. With wind nearly out of the north, the fall meteorological set makes terminal access traffic and automotive parking and the major concentration of regional sources centered in the Atlanta CBD important for air quality levels at the ramp area. When the wind comes from the southwest, as in the summer, aircraft activity assumes primary importance for the air quality levels at the ramp area. The relative changes from 1973 to 1980 between automotive traffic emissions and aircraft emissions generate the air quality trends shown in Fig. 36. By 1980 air quality levels are definitely higher in the summer for all three pollutants, following the trend to increased relative size of the aircraft emissions. Retarding of the growth of aircraft emissions particularly of carbon monoxide and nitrogen oxides that will accompany the transition to new engine emission control standards in the decade 1980-1990 is also reflected in the distinct flattening of the summer growth curves for that period. Fuel storage areas are present both north and south of the aircraft ramp area and lessen the contrast between the changes in summer and fall for hydrocarbon concentrations. Perhaps the most important observation to be made from the baseline curves in Fig. 36, however, is that pollutant levels in the ramp area continue to rise regardless of wind direction. For hydrocarbons and nitrogen oxides, these rises proceed from levels which already present problems with regard to ambient air quality standards.

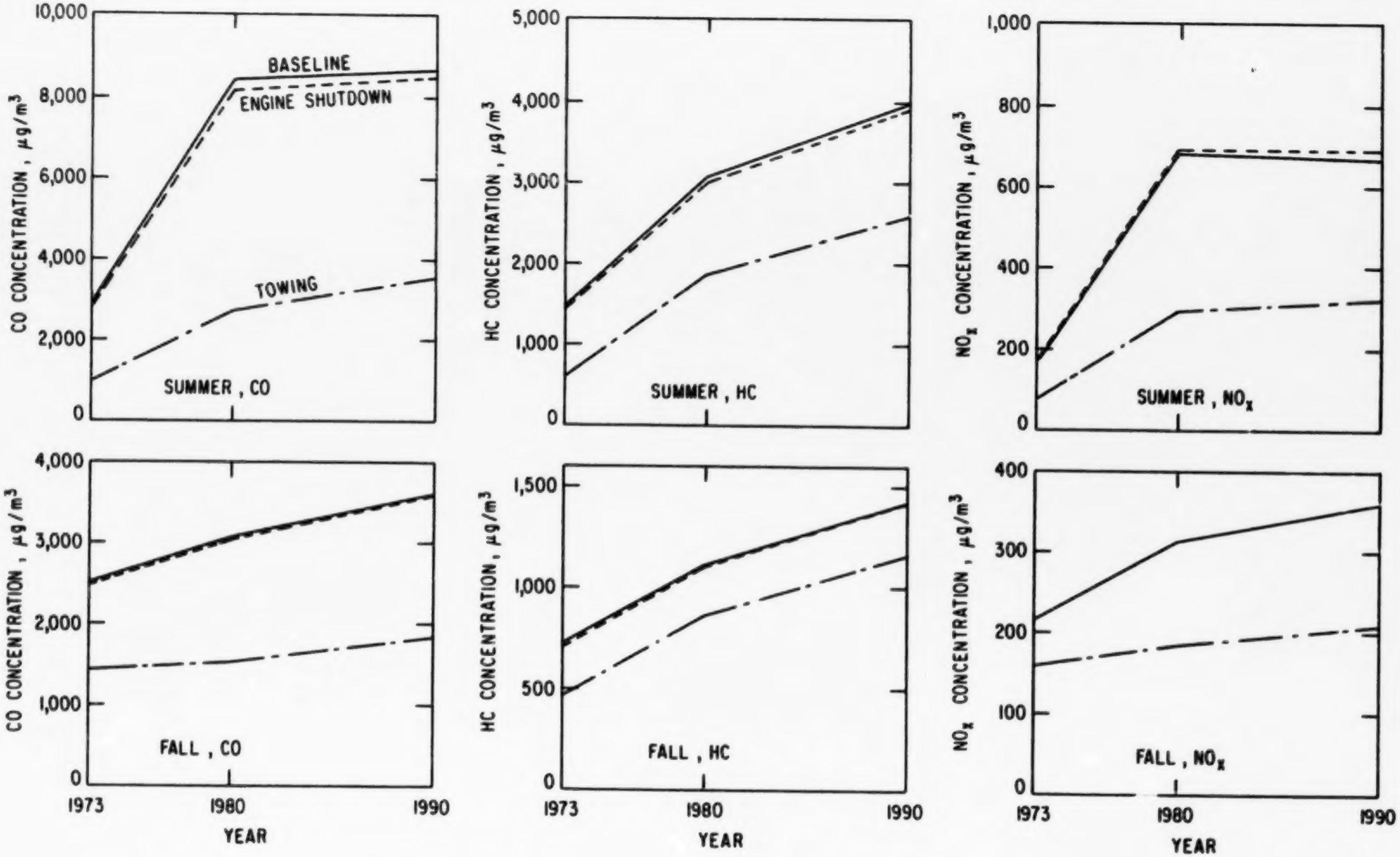

Fig. 36. Pollutant Concentrations at the Aircraft Ramp Area through 1990

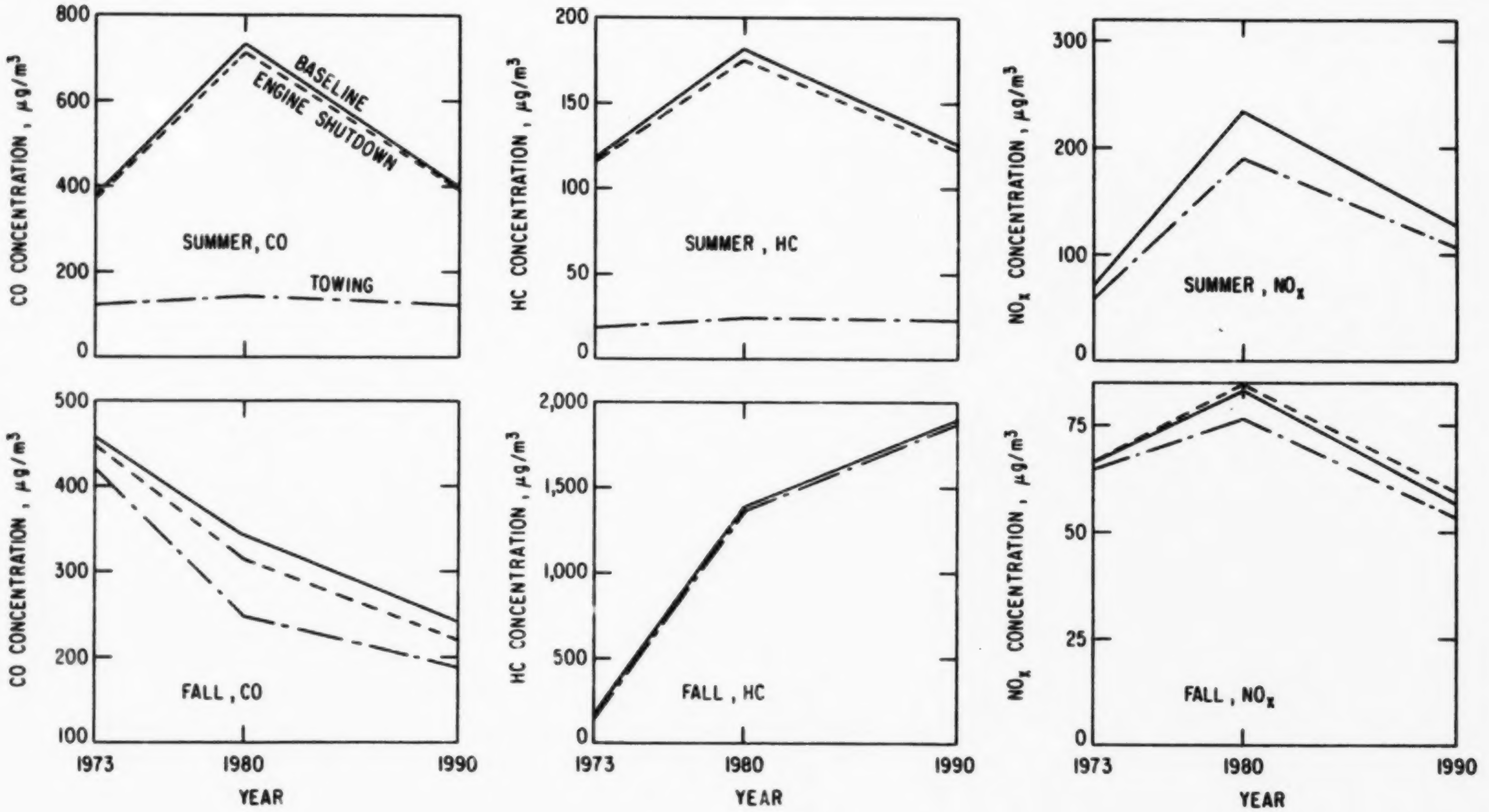

Fig. 37. Pollutant Concentrations at the Airport Central Fire Station through 1990

The factors that influence the changes in baseline concentrations in the ramp area also explain the effects of the two control strategies tested. Engine shutdown effects a small change in concentrations only for summer conditions during which aircraft taxi emissions are a dominant factor. Towing produces a much larger change and, likewise, is more effective for summer conditions. Towing is most effective in controlling CO concentrations, which, however, do not represent serious problems over the time span examined here. The changes in HC and NO_x produced by the towing strategy are appreciable, but, nevertheless, are insufficient alone to bring these pollutants within standards in the ramp area.

Pollutant concentration trends at the central fire station can similarly be analyzed by considering the changes in emissions from the source types that are dominant for differing wind directions. It is sufficient to note from Fig. 37 that the increases in summer concentrations caused by growth in aircraft activity between 1973 and 1980 are largely counteracted by the combination of new aircraft engine emission standards and continuing decline in automotive emissions from 1980 to 1990. For fall, a mixed set of circumstances makes the temporal patterns less repetative among the three pollutants. Aircraft taxi-idle makes a small enough contribution to the fall CO levels for the trend to resemble that of the environs. Takeoff and landing do have greater effect, however, causing the nitrogen oxide levels to follow aircraft NO_x emission trends. Hydrocarbon emissions from the tank farm that is immediately upwind of the fire station in the fall overwhelm contributions from all other sources and cause the only worsening conditions in the period from 1980 to 1990 for the cases considered. Hydrocarbon levels would seem to be the major air quality concern at the fire station through 1990.

Control strategies generally have the expected results. Engine shutdown produces small changes, at best, and towing is not especially effective for fall conditions. The towing strategy in the summer, however, greatly reduces carbon monoxide and hydrocarbon contributions from the outbound aircraft passing by the fire station on taxiway C.

7.3.2 Regional Air Quality

Pollutant emissions from environ sources were shown to remain nearly steady or decrease between 1973 and 1990. This should raise the prospects of generally improving air quality in the region. But how will the substantially increased emissions at the airport affect air quality at downwind locations? A representation of the answer is given by Tables 33-35 that list the pollutant concentrations at three locations directly downwind of the airport.

Pollutant concentrations produced by environ sources do indeed decrease with time at the three locations. Reductions in concentrations from environ sources occur over both time intervals at all three locations for all three pollutants and range between 42% and 65%. For the 1973 to 1980 interval, however, the increase in baseline airport emissions is great enough to cause the total concentrations to increase in every instance. The fractional increases in total concentrations decrease with distance from the airport, but except for CO, they are still substantial 14 km away. Improvements in CO and NO_x levels take place between 1980 and 1990 as a result of reduced aircraft emissions. Hydrocarbon levels, which present the greatest cause for concern, unfortunately continue to rise throughout the second time interval. Although the NO_x levels appear to be quite high, calculated annual averages will show that no single regional location lies directly downwind of the airport often enough for the NO_x air quality standard to be exceeded.

Of the two aircraft emission control strategies examined, towing has much the greater effect on downwind pollutant concentrations. The consistently small improvements in CO and HC levels caused by engine shutdown represent only minor alterations of the basic trends in air quality levels. Towing, on the other hand, produces a reversal of the baseline trend of increasing CO levels between 1973 and 1980 for locations 6 km and 14 km downwind. It is less effective for controlling HC and NO_x levels which follow the baseline trends, although at significantly reduced levels. Even with the towing strategy in effect, hydrocarbon levels at locations close to the downwind edge of the airport are high enough to be of concern. Control of fuel handling emissions must be part of any strategy that attempts to reduce hydrocarbon levels near the airport.

Trends in total pollutant concentrations indicated by Tables 33-35 are displayed as the Fall curves in Figs. 38-40. Also shown are similar curves that describe downwind concentrations for the summer, when the wind is from the opposite direction. At great enough distance (e.g. 14 km in

TABLE 33. Change in Fall Regional Concentrations of CO Downwind of Airport to 1990[a]

Strategy	Source	Downwind Distance from the ALP and Year								
		2 km			6 km			14 km		
		1973	1980	1990	1973	1980	1990	1973	1980	1990
Baseline	Environs	314.	152.	110.	279.	142.	98.	198.	109.	81.
	Airport	541.	1363.	1304.	182.	473.	452.	65.	165.	152.
	Total	855.	1515.	1414.	461.	615.	550.	263.	274.	233.
Engine Shutdown	Environs	314.	152.	110.	279.	142.	98.	198.	109.	81.
	Airport	525.	1319.	1268.	177.	459.	441.	63.	160.	148.
	Total	839.	1471.	1378.	456.	601.	539.	261.	269.	229.
Towing	Environs	314.	152.	110.	279.	142.	98.	198.	109.	81.
	Airport	199.	413.	511.	75.	134.	161.	28.	45.	53.
	Total	513.	565.	621.	354.	276.	259.	226.	154.	134.

[a] All concentrations in $\mu g/m^3$, 1-hr average.

TABLE 34. Change in Fall Regional Concentrations of HC Downwind of Airport to 1990[a]

		Downwind Distance from the ALP and Year								
		2 km			6 km			14 km		
Strategy	Source	1973	1980	1990	1973	1980	1990	1973	1980	1990
Baseline	Environs	39.7	19.2	15.6	36.3	19.7	16.7	25.0	13.9	11.5
	Airport	231.5	479.4	568.3	78.7	219.8	271.0	27.5	82.4	101.3
	Total	271.2	498.6	583.9	115.0	239.5	287.7	52.5	96.3	112.8
Engine Shutdown	Environs	39.7	19.2	15.6	36.3	19.7	16.7	25.0	13.9	11.5
	Airport	221.9	466.3	555.4	75.6	215.4	266.9	26.5	81.0	99.9
	Total	261.6	485.5	571.0	111.9	235.1	283.6	51.5	94.9	111.4
Towing	Environs	39.7	19.2	15.6	36.3	19.7	16.7	25.0	13.9	11.5
	Airport	86.1	261.9	355.4	35.9	140.5	192.2	12.8	54.0	73.8
	Total	125.8	281.1	371.0	72.2	160.2	208.9	37.8	67.9	85.3

[a] All concentrations in μg/m³, 1-hr average.

TABLE 35. Change in Fall Regional Concentrations of NO_x Downwind of Airport to 1990[a]

Strategy	Source	Downwind Distance from the ALP and Year								
		2 km			6 km			14 km		
		1973	1980	1990	1973	1980	1990	1973	1980	1990
Baseline	Environs	53.0	36.7	30.4	44.8	31.3	24.2	29.9	22.9	17.3
	Airport	64.9	236.3	178.8	28.7	108.9	79.6	11.7	44.6	31.7
	Total	117.9	273.0	209.2	73.5	140.2	103.8	41.6	67.5	49.0
Engine Shutdown	Environs	53.0	36.7	30.4	44.8	31.3	24.2	29.9	22.9	17.3
	Airport	65.0	237.9	183.3	28.7	109.3	81.0	11.7	44.7	32.2
	Total	118.0	274.6	213.7	73.5	140.6	105.2	41.6	67.6	49.5
Towing	Environs	53.0	36.7	30.4	44.8	31.3	24.2	29.9	22.9	17.3
	Airport	48.4	168.7	124.1	23.1	84.3	59.1	9.7	35.9	24.7
	Total	101.4	205.4	154.5	67.9	115.6	83.3	39.6	58.8	42.0

[a] All concentrations in $\mu g/m^3$, 1-hr average.

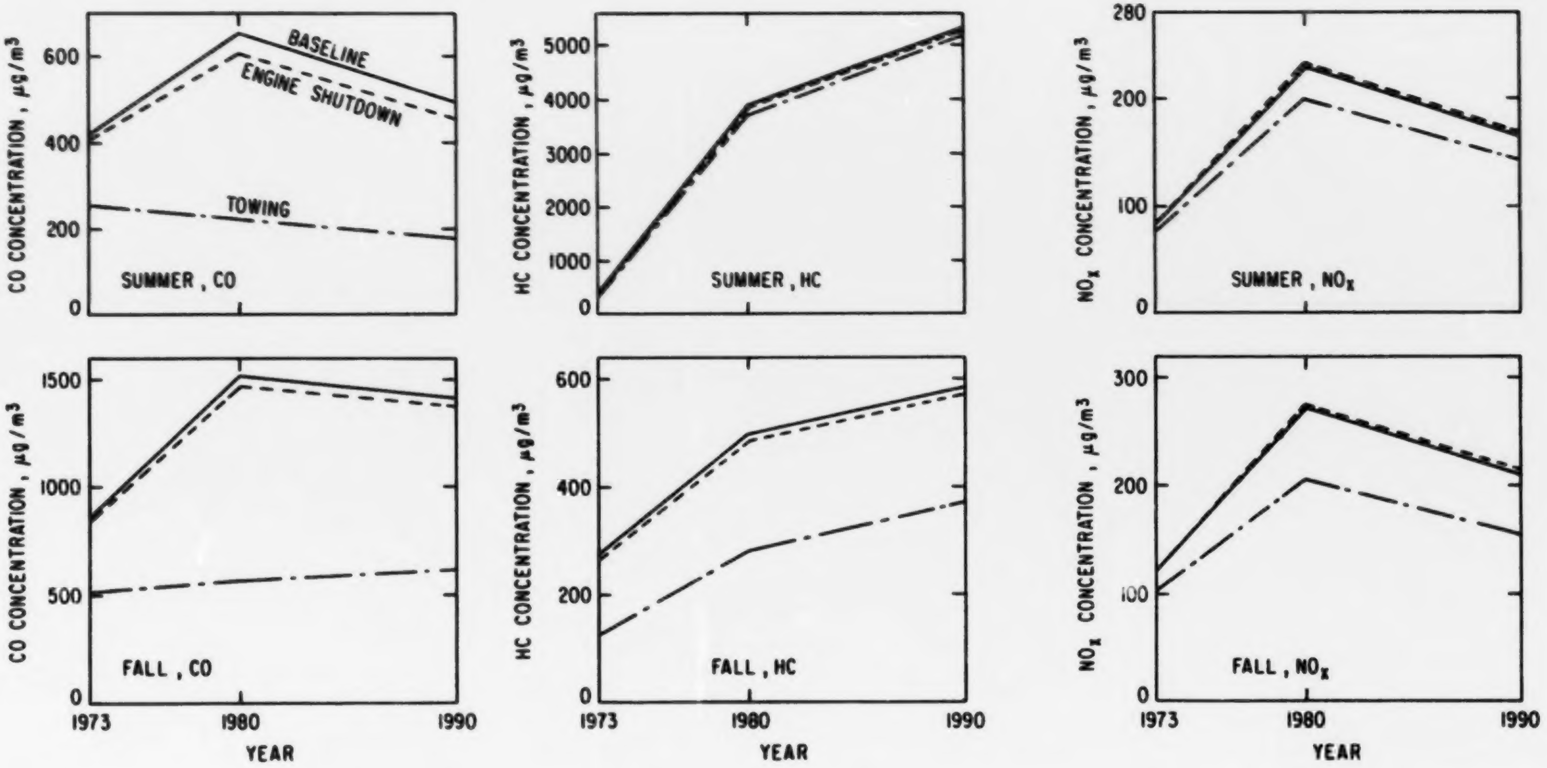

Fig. 38. Regional Pollutant Concentrations 2 km Downwind of the Airport through 1990

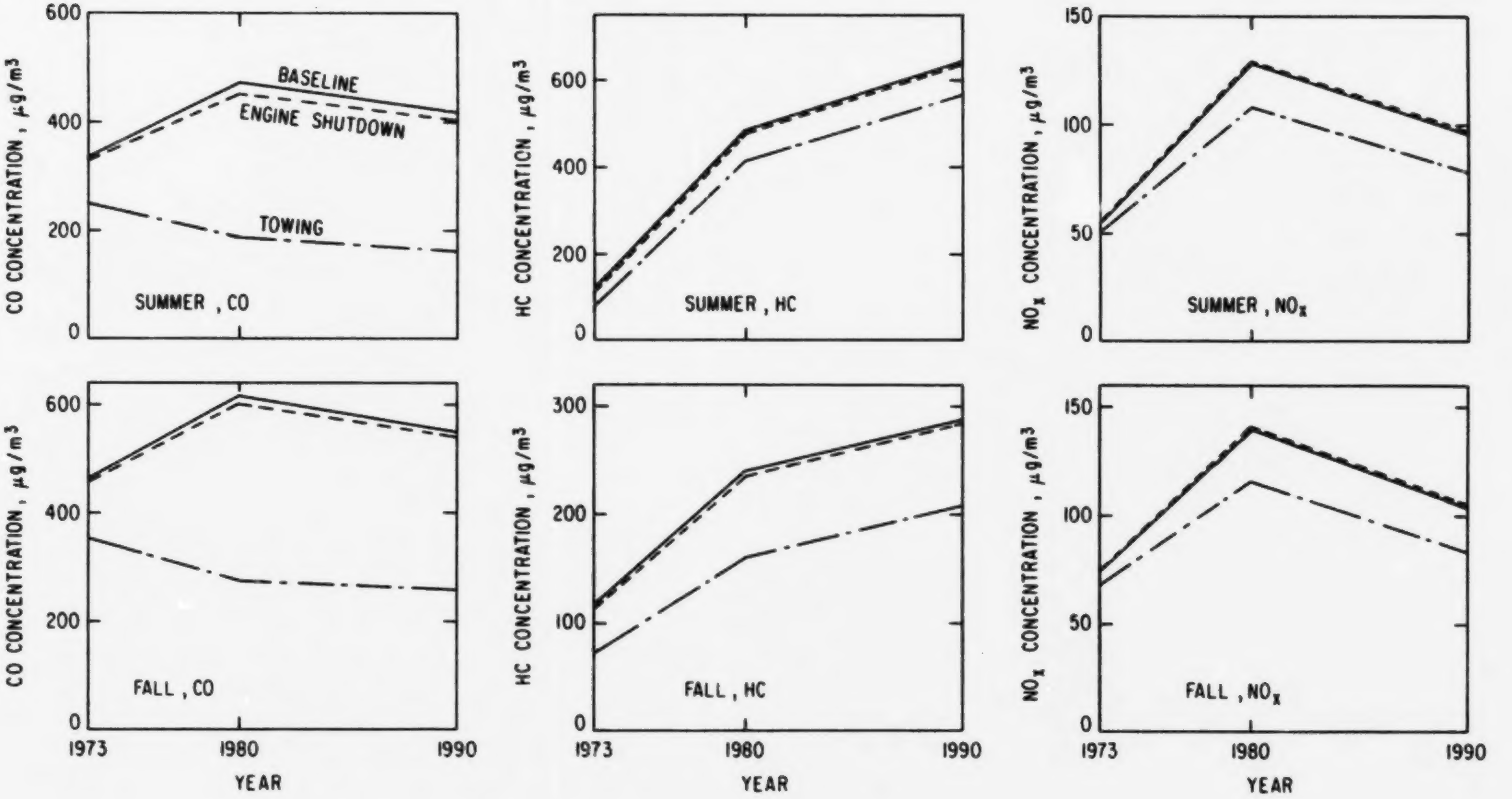

Fig. 39. Regional Pollutant Concentrations 6 km Downwind of the Airport through 1990

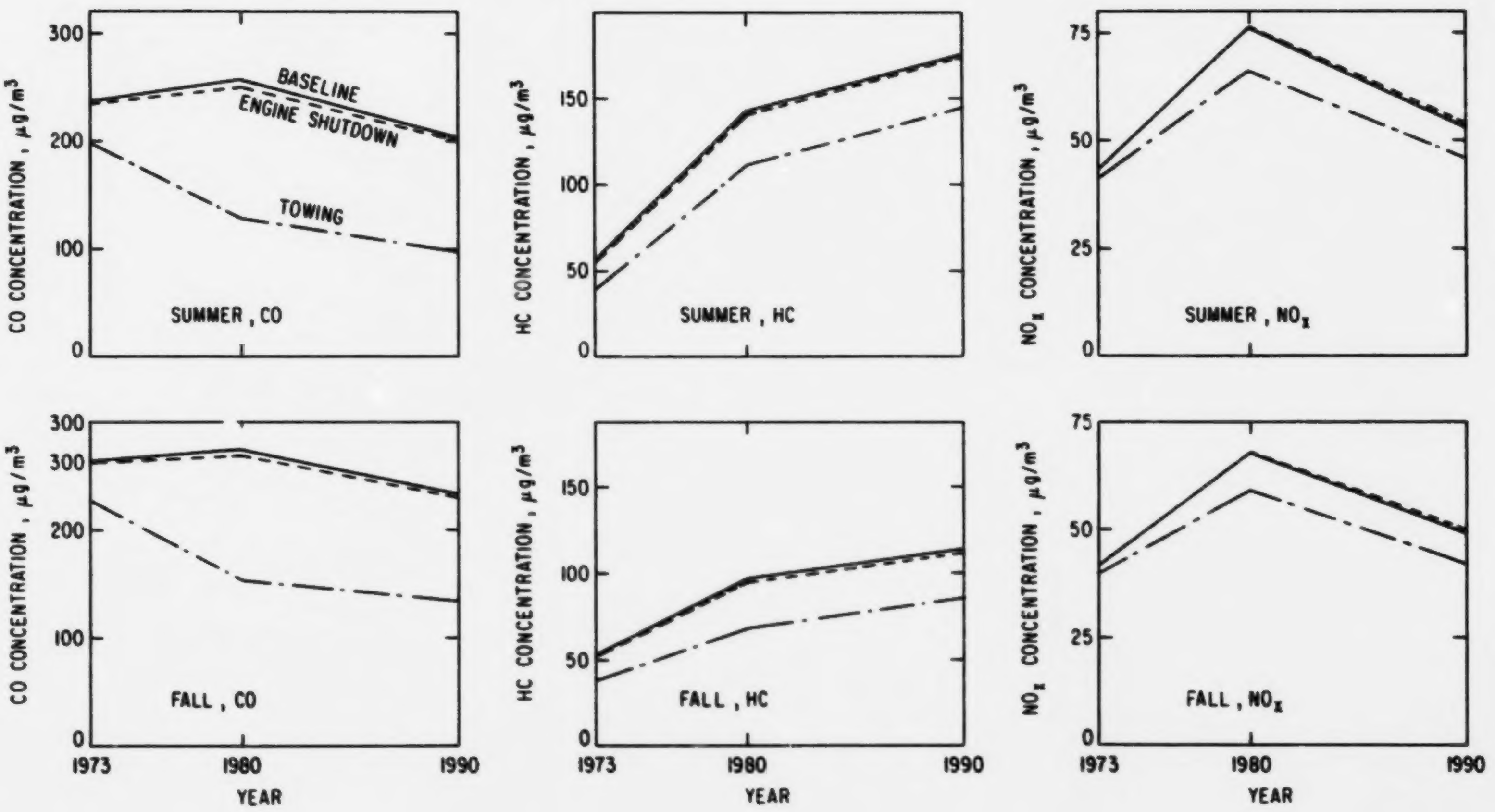

Fig. 40. Regional Pollutant Concentrations 14 km Downwind of the Airport through 1990

Fig. 40) the airport is essentially a point source, and its impact on downwind points is independent of wind direction. Higher hydrocarbon levels at 14 km during the summer than during the fall are caused by increased fuel evaporation losses at higher temperature. For regional locations nearer the airport, spatial details of the airport become important. The concentrations of fuel storage facilities near the northeast perimeter of the airport is reflected in very large HC levels at close in (2 km) downwind locations with a southwest wind.

The effects of the towing strategy on downwind CO levels is considerable even at 14 km. As seen previously, towing is less effective for control of HC and NO_x levels and, naturally, has no effect on high HC levels caused by proximity to fuel storage facilities.

7.3.3 Long-Term Air Quality

Annual average pollutant concentrations for 1980 and 1990 baseline conditions at a number of receptors on and near the airport are summarized in Tables 36 and 37. The concentrations in these tables can be compared with 1973 concentrations for the same set of receptors in Tables 27-29. Of greatest significance in the tables are the annual average NO_x concentrations that can be compared directly with the ambient air quality standard.

On the airport, GEOMET Site No. 2 is located at the central fire station. Table 36 shows that the NO_x standard there is slightly exceeded in 1980, but by 1990 the level is below the standard. For 1980, only the NO_x level at the most remote receptor, GEOMET Site No. 4, is below the NO_x standard. Considerable improvement occurs between 1980 and 1990, but receptors near outbound runways, particularly near runway 8/26 (GEOMET Sites 1, 7, and 8) continue to indicate NO_x levels in excess of the standard.

Long-term NO_x concentrations at the regional receptors 4 km to 6 km from the center of the airport are well below the NO_x standard both in 1980 and 1990. The highest annual NO_x level at regional locations was found in both years at a receptor in the Atlanta CBD, and it is also well below the standard. Figures 41 and 42 show regional isopleth maps of annual average NO_x levels for 1980 and 1990, respectively.

TABLE 36. Annual Average Pollutant Concentrations in the Airport Vicinity for 1980[a]

Receptor UTM-X[b] (km)	Receptor UTM-Y[b] (km)	CO Airport	CO Environs	CO Total	HC Airport	HC Environs	HC Total	NO_X Airport	NO_X Environs	NO_X Total
734.5	3729.5	29.1	130.3	159.4	11.5	70.6	82.1	6.3	31.6	37.9
	3725.5	54.6	128.0	182.6	21.3	63.0	84.3	14.2	31.5	45.7
	3721.5	22.2	104.5	126.7	8.9	50.0	58.9	7.0	26.7	33.7
738.5	3729.5	62.9	157.5	220.4	24.2	85.1	109.3	9.8	40.7	50.5
	3725.5	851.7	139.8	991.5	286.2	72.3	358.5	142.9	39.3	182.2
	3721.5	27.1	119.4	146.5	10.4	54.8	65.2	7.3	31.3	38.6
742.5	3729.5	38.5	148.1	186.6	15.9	80.1	96.0	8.8	39.8	48.6
	3725.5	73.6	137.2	210.8	29.7	71.9	101.6	24.6	38.0	62.6
	3721.5	44.7	130.4	175.1	17.3	60.8	78.1	13.4	32.4	45.8
GEOMET Site	#1	661.2	142.9	804.2	309.8	75.6	385.4	152.4	40.7	193.1
	#2	562.8	136.1	698.9	191.2	67.0	258.2	79.6	37.1	116.7
	#3	189.6	140.7	330.3	70.2	65.9	136.1	98.6	40.8	139.4
	#4	119.1	133.3	252.4	39.5	62.7	102.2	56.8	36.9	93.7
	#5	178.6	142.5	321.1	59.3	65.6	124.9	116.1	42.2	157.3
	#6	379.8	136.7	516.5	150.6	69.5	220.1	72.0	38.1	110.1
	#7	430.3	201.2	631.5	144.8	80.4	225.2	151.8	68.2	220.0
	#8	485.0	145.6	630.6	169.7	75.8	245.5	453.3	42.2	495.5
Airport Location Point		1011.0	139.6	1150.6	343.5	72.8	416.3	153.3	39.4	192.7
Worst Non Airport Receptor		10.3	257.5	267.8	6.7	194.7	201.3	2.1	61.3	63.4
		UTM-X=738.5; UTM-Y=3737.5			UTM-X=746.5; UTM-Y=3717.5			UTM-X=742.5; UTM-Y=3737.5		

[a] All concentrations in μg/m³.

[b] Universal Transverse Mercator coordinate system, zone 10.

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LE 37. Annual Average Pollutant Concentrations in the Airport Vicinity for 1990[a]

Receptor		CO			HC			NO_x		
UTM-X[b] (km)	UTM-Y[b] (km)	Airport	Environs	Total	Airport	Environs	Total	Airport	Environs	Total
734.5	3729.5	31.5	85.3	116.8	14.4	68.4	82.8	4.8	24.7	29.5
	3725.5	57.8	77.1	134.9	26.4	58.9	85.3	10.2	23.7	33.9
	3721.5	23.0	65.7	88.7	10.9	47.1	58.0	4.9	20.5	25.4
738.5	3729.5	67.0	101.9	168.9	30.3	83.9	114.2	7.9	32.1	40.0
	3725.5	684.4	89.1	773.5	282.2	68.5	350.7	98.8	30.4	129.2
	3721.5	28.0	79.3	107.3	12.7	52.2	64.9	5.2	24.7	29.9
742.5	3729.5	38.7	97.9	136.6	19.5	78.3	97.8	6.4	32.1	38.5
	3725.5	69.5	92.1	161.6	35.3	69.8	105.1	16.9	30.4	47.3
	3721.5	43.0	90.4	133.4	20.4	58.6	79.0	9.2	25.7	34.9
GEOMET Site	#1	609.4	92.5	701.9	372.2	72.3	444.5	107.9	31.8	139.7
	#2	433.5	88.7	522.2	191.5	63.8	255.4	52.8	29.2	82.0
	#3	168.4	92.6	261.0	78.0	62.8	140.8	60.2	32.7	92.9
	#4	102.3	86.4	188.7	42.1	59.4	101.5	36.1	29.2	65.3
	#5	155.7	88.0	243.7	66.0	61.0	127.0	71.0	32.3	103.3
	#6	344.9	87.2	432.0	172.2	65.8	238.0	51.7	29.6	81.3
	#7	410.1	121.4	531.5	166.3	73.4	239.7	99.6	54.7	154.3
	#8	375.7	95.3	471.0	173.7	73.0	246.7	285.4	33.6	319.0
Airport Location Point		813.5	89.1	902.6	352.4	69.1	421.5	105.3	30.4	135.7
Worst Non-Airport Receptor		7.1	177.8	184.9	7.9	272.3	280.2	1.5	51.0	52.5
		UTM-X=742.5; UTM-Y=3737.5			UTM-X=746.5; UTM-Y=3717.5			UTM-X=742.5; UTM-Y=3737.5		

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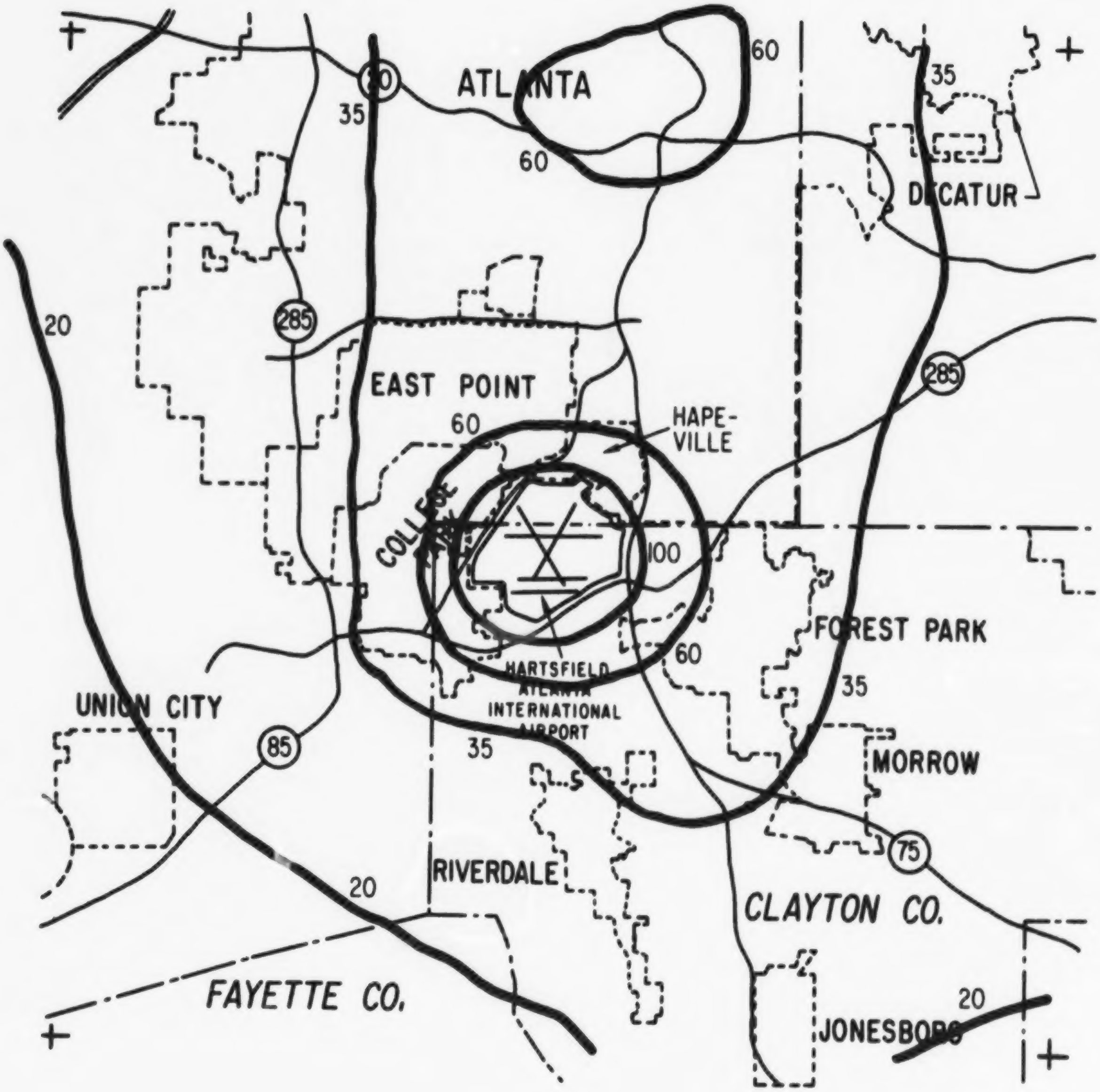
[a] All concentrations in μg/m³.

[b] Universal Transverse Mercator coordinate system, zone 16.

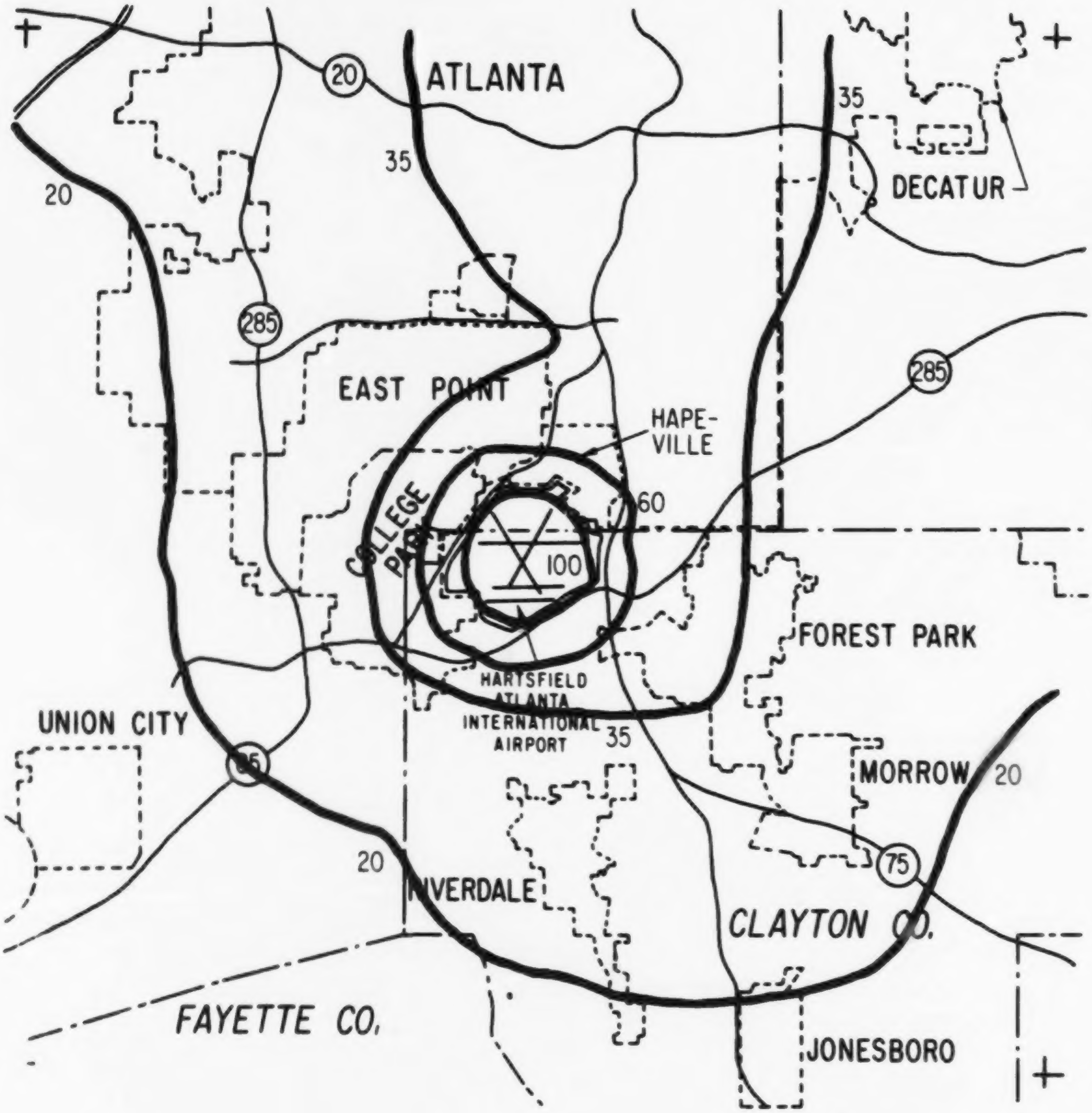
ALL CONCENTRATIONS IN $\mu G/M^3$, ANNUAL AVERAGE



ATLANTA
60
35
20
60
35
DECATUR
20
285
EAST POINT
60
HAPE-VILLE
285
COLLEGE PARK
100
FOREST PARK
60
HARTSFIELD ATLANTA INTERNATIONAL AIRPORT
35
UNION CITY
85
35
MORROW
75
RIVERDALE
20
CLAYTON CO.
FAYETTE CO.
20
JONESBORO

Fig. 41. Annual Average NO_x Concentrations under Baseline Conditions for 1980

ALL CONCENTRATIONS IN $\mu G/M^3$, ANNUAL AVERAGE


ATLANTA
20
35
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DECATUR
285
EAST POINT
HAPE-
VILLE
COLLEGE PARK
60
100
FOREST PARK
HARTSFIELD
ATLANTA
INTERNATIONAL
AIRPORT
35
UNION CITY
85
MORROW
20
75
20
RIVERDALE
CLAYTON CO.
FAYETTE CO.
JONESBORO
285
35

Fig. 42. Annual Average NO_x Concentrations under Baseline Conditions for 1990

Although HC levels summarized in Tables 36 and 37 are not directly comparable with the 3-hr HC standards, annual average levels higher than the 3-hr standard indicate a perennial problem, as noted in Section 6. Annual average HC levels exceed the 160 $\mu g/m^3$ value at several airport locations in both 1980 and 1990. For only one regional receptor does the HC level exceed 160 $\mu g/m^3$. That receptor is nearly coincident with a paint factory included in the point source inventory, and the long-term HC level there receives little contribution from the airport.

8.0 AIRPORT PLANNING AND AIR QUALITY

The previous sections have shown that airport operations can and do have a significant impact on air quality both on the airport site itself and in adjacent areas. The analyses have shown, within the limitations of the analytical model used, the need for some form of emission control strategy to insure attainment of the National Ambient Air Quality Standards. Several such strategies have been evaluated in this report and others have been suggested although not studied here. The purpose of this section is to provide an overview of the procedure by which airports are designed and operated and to indicate where air quality control strategies might be incorporated into the overall plan.

8.1 THE PLANNING PROCESS

The planning of an aviation facility or group of facilities is an exceedingly complex task owing to the multitude of interested groups, varying requirements, and multifaceted implications of air transport. The federal government early recognized the national significance of aviation and the Civil Aeronautics Act of 1938 was a first attempt to systematically evaluate airport needs and to provide some vehicle for federal financial assistance to airport development. Passage of the Federal Airport Act of 1946 led to the generation of the National Airport Plan (NAP), which was an identification of a set of airports throughout the country that were of sufficient importance to be considered for federal funding of development projects. The NAP underwent some evolutionary changes, with a significant shift in focus coming from the Federal Aviation Act of 1958. This act defined the role of the Civil Aeronautics Board (CAB) as the air transportation regulatory agency and established the Federal Aviation Administration, which was to be responsible for promoting civil aviation and establishing safety and air space utilization regulations. At this point the NAP began to take on a longer time horizon and consideration was being given to projecting future airport requirements as well as current needs. The Airport and Airway Development Act of 1970 represents the most recent significant change in the airport planning process. (A concise history of airport planning is presented in Ref. 22.) As currently practiced under the guidelines of the 1970 Act, airport planning operates on three fundamental levels: system planning, master planning, and development planning. System planning takes place on national, regional, and local scales.

8.1.1 National Airport System Plan

By mandate of the Act, the Federal Aviation Administration is responsible for the preparation of a National Airport System Plan (NASP). This plan replaces the National Airport Plan and is designed to determine national civil aviation needs both current and extending ten years into the future. The NASP is to be revised on a regular basis and its development is to be coordinated with other federal agencies to provide a plan that is consistent with total transportation requirements. Airports included in the NASP are those that serve public aviation needs (as opposed to those serving local interests only) and they must be considered in relationship to other means of intercity travel and in the context of the total airport environment, not the airfield only.

The NASP serves as a guideline to the Congress and to the FAA in the awarding of funds under the Airport Development Aid Program (ADAP). Airports must be included in the NASP to be eligible for ADAP funding, although such inclusion does not guarantee that funds will be available. In the NASP, airports are grouped into primary system, secondary system, and feeder system categories based on the number of enplaned passengers. Annual enplanements totaling 50,000 and 1,000,000 divide the three classes. Each class is subdivided into high, medium or low density groups based on aircraft activity. Table 38 summarizes the classification system.

TABLE 38. Airport Classification System for National Airport System Plan[a]

Airport Category	Annual Enplaned Passengers	Annual Aircraft Operations
Primary System	More than 1,000,000	
High density		More than 350,000
Medium density		250,000 to 350,000
Low density		Less than 250,000
Secondary System	50,000 to 1,000,000	
High density		More than 250,000
Medium density		100,000 to 250,000
Low density		Less than 100,000
Feeder System	Less than 50,000	
High density		More than 100,000
Medium density		20,000 to 100,000
Low density		Less than 20,000

[a] Reference 23

All existing airports receiving airline service certified by the CAB are included in the NASP. New and replacement airports that provide air carrier service are also included. Regional airports that provide service to more than one community are incorporated along with public-use STOLports (Short Takeoff and Landing) and heliports. General aviation facilities are evaluated on the basis of their interface with public civil or military aviation needs prior to inclusion. Table 39 gives a summary of the current National Airport System and projections to 1982. Of significance is the large increase in the high density, primary system airports.

TABLE 39. National Airport System, 1973-1982[a]

Airport Category	1973 Number of Airports	1982 Number of Airports
Primary System		
High density	12	50
Medium density	14	30
Low density	28	25
Secondary System		
High density	31	253
Medium density	185	250
Low density	174	342
Feeder System		
High density	61	193
Medium density	795	1,706
Low density	1,940	1,800
Total:	3,240	4,649

[a] Reference 24

.1.2 Local Airport System Plans

The regional, statewide, or metropolitan system planning process is designed to "determine the extent, type, nature, location, and timing of airport development needed in a specific area to establish a viable and balanced system of public airports. It includes identification of the specific aeronautical role of each airport within the system, development of estimates of system-wide development costs, and the conduct of such studies, surveys, and other planning actions as may be necessary to determine the short-intermediate, and long-range aeronautical demands required to be met by a particular system of airports."[23] One of the significant features of the Airport and Airway Development Act of 1970 is that is provides for planning grants, not to exceed 2/3 of the project cost, to planning agencies for the preparation of a system plan.

Under a system planning grant, all work related to the generation of aeronautical demand forecasts for a region and the development of a plan to satisfy those demands are eligible for funding. Typical of the types of efforts that are included are: inventory of airports, aeronautical activity, land use plans, socioeconomic factors, financial resources; forecasts of aviation demand in terms of airport users, air traffic activity, fleet mix; capacity analyses of airspace, airfields, terminals, ground access; determination of airport requirements and alternative systems to meet the demand; schedule of plan implementation and development costs; management plans.[25] Detailed plans for individual airports are excluded at this level.

In awarding grants, priority is given to system plans that are a part of a Department of Housing and Urban Development planning program (e.g., as under the Comprehensive Planning Assistance Program authorized by Section 701 of the Housing Act of 1954) and/or are part of a comprehensive multimodal transportation planning effort. The emphasis is given in an attempt to integrate airport planning into a total regional planning perspective.

8.1.3 Airport Master Plans

Master plans are designed to present an overall development program for an individual airport and the land uses adjacent to the airport. Under the 1970 Act, public groups are eligible for master planning grants, also limited to 2/3 of the total project cost.

The master plan is made up of four phases.[26] The Airport Requirements Phase consists of the following: an inventory of existing facilities, socioeconomic data, other planning efforts, financial resources; a forecast of aviation demand for the airport; a demand/capacity analysis for the airfield terminal, ground access; a facility requirement determination; a study of environmental implications of the airport. The Site Selection Phase is the choice of the location of a new airport. The Airport Plan Phase includes th development of an airport layout plan to include runways, terminals, navigational facilities; a land use plan for the airport-owned land and the adjacent areas; a terminal area plan; and an airport access plan. The Financial Plan Phase includes schedules of proposed development, estimated development costs, a study of the economic feasibility of the plan, and a financing program.

Master planning grants are given on a priority basis to airports experiencing severe operational restrictions, airports in need of congestion relief, and airports needing expansion to accommodate new equipment or those experiencing marked environmental problems. Environmental studies, which are part of the master planning process, are confined to the airport boundaries to be eligible for grant funds. Studies for the solution of environmental problems outside the airport and land use planning for the areas adjacent to the airport boundary are not eligible tasks.[23]

8.1.4 Airport Development Plans

The airport development plan is the most specific of the planning programs. It outlines the details of a specific project to be carried out at an airport. It represents the final step before blueprints are drawn and construction is begun.

Airport development projects are eligible for federally-assisted funding under the Airport Development Assistance Program (ADAP). The ADAP program provides 50% federal funds for all approved programs. Project applications are given a priority rating based on (1) work essentiality, (2) functional role of the airport in the NASP, and (3) timing of the need for the project. Typical ADAP-funded projects include new airport construction, runway additions and extensions, installation of navigational equipment, expansion of terminal and cargo facilities, and expansion of entrance and service roads.

8.2 OPERATIONAL PROCEDURES

The operation of an airport, especially a large air carrier facility, is an exceedingly complex task owing to the large number of public and private organizations that must coordinate their activities to provide safe and efficient airport functioning. Four components of the operational structure can be identified as being in a position to affect airport operations to achieve air quality control. They are (1) federal regulatory agencies, (2) state or local regulatory agencies, (3) airport operators, and (4) airport users.

8.2.1 Federal Agencies

The two federal agencies that have the greatest influence on airport operations are the Civil Aeronautics Board (CAB) and the Federal Aviation Administration (FAA). There are other agencies that exert indirect or peripheral influence but these two maintain prime responsibility.

The Civil Aeronautics Board, as was mentioned previously, was given the role of an independent regulatory organization by the Federal Aviation Act of 1958. Its main function is to control air carrier routes, capacities, and fares. In the highly competitive air transport market, the CAB controls the level of service between any two points through its certification program. An airline seeking to establish or discard service along any route must receive authorization from the CAB. The regulatory process is designed to insure that all communities that require air transport services will get an adequate share and that certain high-profit routes will not become saturated with available seats while other routes suffer chronic shortages. In addition to regulating route capacity, the CAB controls air fares and non-scheduled flight activity.

The CAB plays a regulatory role in relationships between air carriers. Mergers, route agreements, and competitive practices are subject to review and approval by the CAB. The Board has the authority to institute court proceedings against any aviation organization in violation of its regulations. Board decisions may be appealed to the United States Courts of Appeal, which have exclusive authority to rule on Board orders.[27]

The Federal Aviation Administration is a part of the Department of Transportation and is a technically-oriented organization as opposed to an economically-oriented group such as the CAB. The FAA assumes prime line responsibility for the operation of airports through its mandate to staff and equip airport control towers. The air traffic controllers are FAA employees and every function on the airport involving the movement of aircraft must meet with established FAA guidelines and regulations. In addition, the FAA has authority to certify aircraft and aircraft engines as to their airworthiness. Absence of such certification would prohibit the introduction of the equipment into service.

The FAA assumes the primary role in aviation safety. It has the ability to issue "rules, regulations, and minimum standards relating to the manufacture, operation and maintenance of aircraft."[27] In addition, it certifies pilots and airports and performs routine safety inspections of air navigation facilities.

The FAA is active in research and development in improved aeronautical equipment for civil aviation. Aircraft, propulsion systems, navigational aids, air traffic control procedures and systems and noise reduction are among the areas of intensive research. The FAA maintains an interface with the National Aeronautics and Space Administration (NASA) in this regard.

The role of the FAA in airport planning has already been described.

In some areas the CAB and the FAA play an interlocking role in the operation of an airport. If, for example, the FAA should determine that congestion at a particular airport is creating an unsafe traffic control situation, the CAB could be called upon to change its route certifications and force diversion to other facilities. Close cooperation between the agencies is essential to provide a unified airport operational structure.

8.2.2 State or Local Regulatory Agencies

In some areas a state or local government agency has discretionary authority over airport operations. In all cases, however, the applicable minimum requirements of the FAA and the CAB must be met.

The agency that has the most direct impact on airport operations is the airport authority and/or the local government, which has the responsibility of running the airport within FAA and CAB guidelines. In this case, the local agency is, in effect, an airport operator. This role is discussed in the next section.

Some regions have a state or metropolitan aviation department that serves to set aviation policy for the area. This function lies primarily in the planning realm but the studies, surveys, and recommendations of the agency can impact on day-to-day operations. For example, the decision of an agency to promote alternative airport utilization can foster an FAA or CAB decision to change operating procedures to accommodate local desires.

8.2.3 Airport Operators

The airport operator is responsible for the day-to-day functioning of the airport activities that are not under the control of the FAA. The operator may be a private, public, or governmental organization or an individual and is considered as the chief sponsor and proponent of the airport. He is the manager of the airport and has the responsibility for airport maintenance, security, provision and care of public facilities (e.g., parking lots, terminal buildings, etc.), and financial management, including the collection of airport user fees and the securing of funds for airport projects.

With regard to operational procedures, the operator must function within FAA guidelines. Nothing can hamper aircraft or passenger safety and an operator stands to lose his certification for failure to comply with appropriate regulations. In this respect the operator's role is fairly structured and restricted to established protocols.

The operator plays a major role in airport development and is generally heavily involved in the planning process, particularly master planning. In this way, he can influence operational procedures by developing a plan that will suit his requirements as well as those of other agencies. For example, an airport authority may choose, in the preparation of a master plan, to foster the use of remote parking areas for aircraft, and the plan can be designed with this feature and still be in compliance with FAA rules.

8.2.4 Airport Users

Airport users include a wide variety of special interest groups all with the same common interest in making use of the air transportation facility. Airlines, both passenger and cargo, general and business aviation interests, passengers, shippers, and commercial service facility operators make up the heterogeneous mixture of airport users. Each group affects the daily operational pattern of the airport and each can serve as the focal point of some form of control strategy for air quality management.

As an example, airlines can determine the procedures that their pilots will follow within the bounds of FAA guidelines. An engine shutdown procedure can be incorporated into an airline's operations manual irrespective of the procedures followed by other airlines at the same airport. The choic of equipment used on each route can be determined by the airline within the constraints of the CAB-approved capacity agreements.

Commercial service facility operators such as food service companies, fuel companies, and the like can determine their own methods of providing their services. These methods can be developed to minimize air quality impacts; for example, emission-controlled vehicles can be used on the airport.

8.3 ENVIRONMENTAL ASSESSMENTS

There are several points in the airport planning and operational procedures where environmental impact assessment must be performed and control strategies must be recommended in accordance with federal and local law. There are also numerous points where an assessment and strategy choice can be made although not required under current regulations. Table 40 lists the principal air quality control programs and their impact on airport functioning.

8.3.1 Environmental Impact Statement

The Environmental Impact Statement (EIS) has, to date, had the most direct impact on airport planning. Under the National Environmental Policy Act of 1969, all federal activities that have a significant impact on the environment must have an EIS prepared to detail the expected effects. This requirement affects airport master planning and development planning.

The preparation of an EIS during master planning is an option of the airport sponsor, with the exception of two situations where it is required: a master plan study that involves the selection of a site for a new airport must have an EIS prepared, and any transfer of federally-owned land for civil aviation use must be accompanied by an EIS. At all other phases of master planning, environmental review is encouraged although not mandated. Master planning grant funds may be used for the preparation of an EIS for a project that is expected to have significant environmental impact, and this statement may serve as the basis for the EIS required under development planning. Grant funds cannot, however, be used for the solution of environmental problems outside the airport boundaries. Likewise, compatible land use planning for the area adjacent to the airport is not eligible under the grant program.[23]

TABLE 40. Air Quality Impact Assessments Required for Airports

Air Quality Management Program	Affected Airport Program	Requirement
Environmental Impact Statement (EIS)	Master Planning	Statement must be filed for site selection study. Statement must be filed to approve transfer of federal land for civil aviation. Statement may be filed for any action with significant environmental impact using master planning grant funds.
	Development Planning	Statement must be filed prior to application for ADAP funds. Negative declaration may be filed in place of EIS if appropriate.
State Implementation Plan (SIP)	System Planning Master Planning Development Planning Operation	Demonstrate attainment of NAAQS.
Transportation Control Plan (TCP)	Master Planning Operation	Demonstrate attainment of NAAQS through controls on mobile sources.
Indirect Source Review	Master Planning Development Planning	Demonstrate attainment and maintenance of NAAQS from sources which attract a significant amount of motor vehicle traffic.
Air Quality Maintenance Planning (AQMP)	System Planning Master Planning	Demonstrate maintenance of NAAQS over 10-year period.
Engine Emission Standards	Operation	Meet emission limits imposed on aircraft and aircraft engines.

Since most airport development projects will be funded in part by the federal government under the Airport Development Assistance Program (ADAP), an EIS is required at all times. The statement must precede application for ADAP funding, and, if appropriate, a negative declaration indicating that no significant environmental impact will be encountered may replace the EIS.

Numerous guidelines have been issued by the FAA, CAB, EPA, and the Council on Environmental Quality for the preparation of Environmental Impact Statements.[28]

8.3.2 State Implementation Plans

Under the Clean Air Act of 1970, the states are required to prepare a plan that shows how they will comply with federal air quality standards. The State Implementation Plan (SIP) impacts on all phases of airport planning and operation since it must demonstrate attainment of the National Ambient Air Quality Standards (NAAQS) throughout the state. Any region that cannot be shown to achieve the NAAQS must have an appropriate control strategy applied to reduce emissions. To date, few of the SIPs have addressed airports directly, because, as has already been stated, airports are responsible for less than 5% of regional emissions. The SIP has impacted on airports through the application of control strategies designed to reduce air pollution on less than a regionwide scale. The three portions of the SIPs that are involved are the Transportation Control Plan (TCP), the Indirect Source Review, and Air Quality Maintenance Planning (AQMP).

A TCP is aimed primarily at reducing emissions from mobile sources where they contribute to local air quality problems. Several states, including California, New York, New Jersey, Pennsylvania, and Texas have incorporated emission reduction strategies for airports into their TCP. Control techniques relied primarily on modified ground operations and the strategies were estimated to result in a 1-10% reduction in CO and HC emissions. Depending on the reductions needed to attain the NAAQS, this type of control, if it is as effective as designed, could make a significant contribution to air quality management.

Airports are one of several types of facilities included in Indirect Source Review programs. The EPA has mandated that facilities that generate large volumes of motor vehicle traffic should be subject to an evaluation of whether or not the NAAQS will be violated as a result of the motor vehicle emissions. New or modified airports with more than 50,000 operations per year or more than 1.6 million passengers are subject to this review. The review procedure results in the issuance or denial of a permit to begin construction or modification. As such, the procedure impacts primarily on airport master planning and development planning. Regulations for the preparation of an indirect source review for airports have recently been revised[29] with a note that new guidelines will be published shortly.

There is, of necessity, some overlap between the indirect source review and the environmental impact statement preparation. In an ideal situation the air quality analysis that is prepared for the one should be adequate for the other. In some instances the indirect source review may force an EIS effort earlier in the planning process (e.g., during master planning where an EIS is not required in all cases).

The Air Quality Maintenance Planning program (AQMP) is designed to insure that the NAAQS will not only be attained but maintained when regional growth is considered.[30] As was shown in Phase I of this project,[1] airports can serve as significant inducers of land development as commerce and industry locate to take advantage of the improved transportation network, both ground and air, which accompanies an airport. Airport facilities are, and of necessity should be, an integral part of the regional planning process and fall, therefore, under the analyses to be performed in an AQMP program. Airport system planning and master planning are ideal points at which to incorporate AQMP analyses as the focus of both is long-range projections of activity.

8.3.3 Engine Emission Standards

The emission limits promulgated by EPA[5] are the most direct form of environmental control applied to aircraft and airports. The responsibility for meeting the standards falls primarily on the engine and airframe manufacturers with the FAA playing an overall evaluation role to insure that safety considerations are not being compromised. The primary impact, therefore, is on the airport users and hence on airport operational procedures.

8.4 STRATEGY IMPLEMENTATION

The final point to be considered here is where in the airport design and operation procedures the control strategies studied here can be implemented. Table 41 lists the five control options studied and their most likely point of implementation.

TABLE 41. Implementation of Air Pollution Control Strategies on Airports

Strategy	Implementation Point
Engine Shutdown	Operations Can be implemented at an existing airport with minimum disruption.
Towing	Operations, Development, and Master Planning Requires modifications to aircraft structure, major reorganization of operations. A new airport could be designed for this strategy.
Capacity Control	National Airport System Planning, Airport System Planning Requires consideration of national and regional air transport needs. CAB currently has authority to regulate route capacity.
Fleet Mix	National Airport System Planning, Airport System Planning, Operations Requires consideration of national and regional air transport needs. Within CAB capacity regulations carriers have the option of choosing the aircraft equipment to use.
Engine Emission Standards	Operations Impact is on manufacturers of engines and airframes.

The engine shutdown, capacity control, and fleet mix strategies can be implemented at an existing airport with minimum disruption of normal airport operating procedures. The latter two, however, must be viewed in the context of national, or at least regional, air transportation requirements. The CAB currently possesses the authority to regulate routes and capacities and could play a key role in the use of capacity control or fleet mix control. Either strategy would present a major impact on airline economics and must be thoroughly evaluated prior to implementation.

Towing presents special difficulties because technological changes would be necessary to accommodate its widespread use. As was previously mentioned, current aircraft and tow tractors are not designed for this procedure and structural refit programs would be needed. Airport operational routines would have to undergo substantial review to insure safety and to minimize delays. It is conceivable that an airport might be designed for this strategy (e.g., with special return taxiways for aircraft with equipment problems, or with a towing belt on the taxiways).

The engine emission standards represent a strategy that would have no effect on current airline or airport operations but would require the greatest technological innovations to realize. New generation engines would be required to meet the standards, and a gradual phasing in of aircraft equipped with the new engines mandates that this is a long-term program and offers little in the way of air quality control in the short term.

9.0 SUMMARY AND CONCLUSIONS

As a result of this program several important conclusions have surfaced.

Field Test Program

The field test of the engine shutdown strategy at the Atlanta airport was, at best, inconclusive. Although no operational problems were encountered, no air quality improvement correlated to aircraft activity changes was observed.

Observed air quality data was of questionable validity due to the short test period, equipment difficulties, and the shortage of jet fuel in the midst of the program.

Model Validation

The Argonne Airport Vicinity Air Pollution (AVAP) model did not correlate well with the observed air quality data collected during the field test. The problems with the observed data make a conclusive statement about the model validity impossible.

In general, the model appears to be underpredicting CO concentrations based on a limited validation analysis.

Airport Air Quality

In terms of emission reduction, the application of engine emission standards has the largest impact of the five strategies tested. It is also the only strategy to achieve significant NO_x emission reductions.

Fleet mix and towing achieve significant CO and HC emission reductions but the fleet mix change has the disadvantage of substantially increasing NO_x emissions. Engine shutdown and capacity control show only small emission reductions.

Under normal meteorological conditions there do not appear to be any problems with attainment of the National Ambient Air Quality Standards (NAAQS) for CO. The potential for violations of the HC and NO_x standards is evident with high concentration levels being calculated for these pollutants.

None of the five strategies studied is adequate alone to reduce the HC and NO_x levels below those specified by the NAAQS.

Towing, engine emission standards, and fleet mix controls provide the greatest CO and HC air quality improvements in that order. Only the engine emission standards provide significant NO_x air quality improvement. Engine shutdown and capacity control provide only small improvements.

Towing derives an added air quality improvement by its alteration of the spatial emission pattern as well as its overall emission reduction.

Regional Air Quality

The airport has a noticeable impact on air quality immediately downwind of it, although the effect diminishes substantially with lateral distance from the wind line.

There are indications that airport sources are not causing any regional difficulties with attainment of the NAAQS for CO, are causing significant problems with the HC standard, and are causing some minor violations of the NO_x standard but confined mostly within the airport boundary.

The airport is roughly equivalent to the Atlanta CBD in terms of the air quality impact it produces.

None of the strategies alone is capable of insuring compliance with the HC standard, primarily because of the large concentrations stemming from environ sources.

The engine emission standards reduce the impact of the NO_x violations to small areas at the ends of the runway and entirely within the airport boundary.

Growth Impacts

In the period from 1973-1990 regional emissions of CO are expected to decline dramatically, while emissions of HC and NO_x are expected to remain about constant or increase slightly. The primary trend-setters are the control of motor vehicle emissions and the increases in vehicle-miles-traveled that tend to counteract each other.

Airport sources are expected to increase from their current level of less than 5% of the regional emission total, to around 10% in 1990. The application of engine emission standards between 1980 and 1990 arrests the growth of airport emissions and prevents their increase to greater relative strength. In fact, the standards decrease the relative magnitude of the airport NO_x emissions between 1980 and 1990.

On the airport, the growth in air traffic will result in increases in pollutant concentrations at some points (e.g., the ramp area) regardless of the control strategy applied. At other points (e.g., the central fire station), the towing strategy can minimize the impact of the growth although it is not capable of changing the trends that are being established by the increase in activity and the application of engine emission standards. Engine shutdown provides little air quality improvement.

Regionally, air traffic growth and control of motor vehicle emissions elevate the airport to the position of a bigger contributor to the pollutant concentrations downwind of it. Towing has the greatest impact on minimizing the growth impacts, but, with the singular exception of CO, does not change the concentration trend. For CO, towing does, in fact, result in a different air quality trend downwind of the airport.

Summary

Based on the above considerations, it appears that the application of engine emission standards will have the greatest overall impact on airport and regional air quality. It has the advantage of not requiring any major disruptions to airport operations and is the only strategy that will effect NO_x emission reductions. Its disadvantage is that it is a long-range solution and will not provide short-term air quality improvement.

Towing appears to have significant potential in CO and hydrocarbon control. Its implementation, however, is difficult and costly.

Fleet mix changes have a drawback of increasing NO_x emissions. It would probably not be advisable to accelerate the pace of change and hence permit the application of engine emission standards to newer aircraft in the fleet.

Engine shutdown and capacity control show only small air quality improvements. Shutdown could be routinely implemented, but the economic impacts of capacity control would relegate its use only to areas requiring maximum emission reduction from all sources.

REFERENCES

1. Norco, J. E., R. R. Cirillo, T. E. Baldwin, J. W. Gudenas. An Air Pollution Impact Methodology for Airports - Phase I. Report No. APTD-1470. U.S. Environmental Protection Agency. Research Triangle Park, N.C. Jan. 1973.

2. Aircraft Emissions: Impact on Air Quality and Feasibility of Control. U.S. Environmental Protection Agency. Research Triangle Park, N.C. July 1972.

3. Aircraft and Aircraft Engines: Proposed Standards for Control of Air Pollution. Federal Register. 37(239):26488-26500. Dec. 1972.

4. Ground Operation of Aircraft to Control Emissions: Advance Notice of Proposed Rulemaking. Federal Register. 37(239):26502-26503. Dec. 1972.

5. Control of Air Pollution from Aircraft and Aircraft Engines. Federal Register. 38(136):19088-19103. Part II. July 17, 1973.

6. MacWaters, J. T., R. C. Koch, S. D. Thayer. Air Quality Measured at Atlanta International Airport Before and During Experimental Aircraft Taxiing Operations. GEOMET Report No. EF-330. June 1974.

7. Review of Atlanta Aircraft Ground Emissions Control Demonstration. Mitre Corp. MacLaine, Virginia. To be published.

8. Cirillo, R. R., J. F. Tschanz, J. E. Camaioni. Argonne National Laboratory. Airport Vicinity Air Pollution Study: The Impact of Modified Aircraft Taxi Procedures on Airport Air Quality. Report No. FAA-RD-74-212. Federal Aviation Administration. Wash. D.C. Dec. 1974.

9. Rote, D. M., et al. Argonne National Laboratory. Airport Vicinity Air Pollution Study. Report No. FAA-RD-73-113. Federal Aviation Administration. Wash. D.C. Dec. 1973.

10. Wang, I. T., D. M. Rote, L. A. Conley. Argonne National Laboratory. Airport Vicinity Air Pollution Study - Model Application and Validation and Air Quality Impact Analysis at Washington National Airport. Report No. FAA-RD-74-132. Federal Aviation Administration. Wash. D.C. July 1974.

11. Wangen, L. E., et al. Argonne National Laboratory. A Generalized Air Quality Assessment Model for Air Force Operations - An Operator's Guide. Report No. TR-74-54. Air Force Weapons Laboratory. Kirtland AFB, N.M. June 1974.

12. Rote, D. M., L. E. Wangen. Argonne National Laboratory. A Generalized Air Quality Assessment Model for Air Force Operations - Technical Report." Air Force Weapons Laboratory. Kirtland AFB, N.M. To be published.

13. Airport Layout Plan Report, William B. Hartsfield Atlanta International Airport. Atlanta Airport Engineers. College Park, Ga. Aug. 1973.

14. Compilation of Air Pollutant Emission Factors. Second Edition. Report No. AP-42. U.S. Environmental Protection Agency. Research Triangle Park, N.C. April 1973.

15. Climatography of the United States, No. 82-9, Decennial Census of United States Climate, Summary of Hourly Observations, 1951-160, Atlanta, Georgia. Weather Bureau. U.S. Department of Commerce. Wash. D.C. 1963.

16. Selected Climatic Maps of the United States. Environmental Data Service. ESSA. U.S. Department of Commerce. p 2-5. Wash. D.C. 1966.

17. Holzworth, G. C. Estimates of Mean Maximum Mixing Depths in the Contiguous United States. Monthly Weather Review. 92(5):235-242. May 1964.

18. Hosler, C. R. Low-Level Inversion Frequency in the Contiguous United States. Monthly Weather Review. 319-339. Sept. 1961.

19. Seasonal Combined Wind Distribution by Pasquill Stability Classes (5). STAR Program, covering the period 1/67 - 12/71 at Atlanta, Georgia. Prepared for the Georgia Department of Natural Resources. Environmental Protection Division by the National Climatic Center. NOAA. Asheville, N.C.

20. Transport Policy Directions. ARC. Sept. 1973 (revised Oct. 1973). The Atlanta Region: Framework for the Future. An Interim Status Report. ARC. May 1974. Printed tabulations of calculated results for 1970, 1980, and 1990 of the "null" transportation scenario.

21. Projections of Economic Activity for Air Quality Control Regions. Prepared by the Bureau of Economic Analysis. U.S. Department of Commerce for the Office of Air Quality Planning and Standards, Office of Air and Water Programs. U.S. Environmental Protection Agency. p 79. Aug. 1973.

22. Bacon, F., E. B. Perrett, Jr. The National Airport System Plan - Its History and Its Potential. SAE Paper No. 710414. National Air Transportation Meeting. Atlanta, Ga. May 1971.

23. The National Aviation System Policy Summary. Federal Aviation Administration. Order No. 1000.27. App. 1. March 1972.

24. The National Aviation System Plan, Ten Year Plan 1973-1982. Federal Aviation Administration. Order No. 1000.27. App. 2. March 1972.

25. Airport Environmental Handbook. Prepared for Department of Transportation by CLM Systems, Inc. Cambridge, Mass. DOT-05-00059. Aug. 1971.

26. Airport Master Plans. Federal Aviation Administration. Report No. AC 150/5070-6. Feb. 1971.

27. United States Government Manual 1973/74. Office of the Federal Register. General Services Administration. July 1973.

28. Nelson, K. E., S. J. LaBelle. Guidelines for Review of Environmental Impact Statements: Airport Projects. Prepared by Argonne National Laboratory for the Environmental Protection Agency, Office of Federal Activities. To be published.

29. Approval and Promulgation of Implementation Plans, Review of Indirect Sources. Federal Register. 39(132):25292-25301. July 1974.

30. Air Quality Maintenance Area Designations. Federal Register. 39(133). July 1974. 39(156). Aug. 1974.

31. Turner, D. Bruce. Workbook of Atmospheric Dispersion Estimates. U.S. Environmental Protection Agency. Research Triangle Park, N.C. 1969.